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MK-FERGUSON CO., INC. WO 3589 (314) 441-8086
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St. Charles, MO 63303

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SUBJECT Transmittal of Site Soil Permeability Data

AUTHOR VanFossen, J.S. TO Beclan, D.E. DATE 12/2/92

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REFERENCED DOCUMENT(S)

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Dr. David E. Bedan
Division of Environmental Quality
Missouri Department of Natural Resources
Post Office Box 176
Jefferson City, Missouri 65102

Dear Dr. Bedan:

TRANSMITTAL OF SITE SOIL PERMEABILITY DATA

A technical memorandum from the Project Management Contractor (PMC) staff is enclosed for your information and review. This document outlines the results of recent data gathering activities relating to leachate permeability of site soils at the Weldon Spring Site. Specific data collected includes:

- Laboratory permeability testing of undisturbed soils with both water and synthesized leachate as a permeant, performed to assess the effects of leachate on permeability.
- Field permeability testing of insitu site soils using a two-state borehole (TSB) procedure.

General conclusions from this effort include:

- Results of TSB testing indicate that in situ hydraulic conductivity is not affected by macropore features such as cracks or fractures.
- Logarithimic mean field permeability values (TSB results) range from 1.28 E^{-08} to 3.34 E^{-09} (cm/s).
- Hydraulic conductivity values obtained under recent efforts are consistent with prior data, and support the suitability of the proposed area for a disposal site.
- Synthesized leachate has no detectable effect on permeability. Logarithmic mean hydraulic conductivity values range from 1.26 E^{-09} cm/s (leachate) to 1.66 E^{-09} cm/s (water).
- These values indicate that a 20 ft layer of site clay soils will retard the migration of hazardous constituents contained in the waste to at least the same degree that 30 ft of material having a coefficient of permeability of 1.0 E^{-07} cm/s would retard the migration of water.

CONCURRENCES
RTG SYMBOL
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This information was collected at the request of the MDNR technical staff. A technical memorandum is enclosed that includes data interpretation, data tables, technical references, example calculations, and graphical presentations of the data. A formal report will be forthcoming.

If you have any questions please contact Ken Lawver of my staff at (314)441-8978.

Sincerely,

for

Jerry S. Van Fossen
Deputy Project Manager
Weldon Spring Site
Remedial Action Project

Enclosure:
As stated

cc w/enclosure:
Dan Wall, EPA
Mimi Garstang, MDNR-DGLS

EW-94:KLawver:x7003:emh:12/1/92 (m:SoilPerm.let)

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WELDON SPRING SITE REMEDIAL ACTION PROJECT
MK-FERGUSON CO., INC. WO 3589 (314)441-8086
7295 HIGHWAY 94 SOUTH
ST. CHARLES, MO 63304

DOCUMENT NUMBER (DIN) 23932
◆DOCUMENT TYPE LR-MKFW-DOEW
ORIGINATORS DCN ______

◆SUBJECT Transmittal of Site Soil Permeability Data To the Missouri Dept of Natural Resources

◆FROM J R Powers ◆TO S H McCracken ◆DATE ______

◆SUBJECT CODE/WORK PACKAGE NUMBER 7-6020

REFERENCED DOCUMENT(S) ______

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WELDON SPRING REMEDIAL ACTION PROJECT
7295 HIGHWAY 94 SOUTH
ST. CHARLES, MISSOURI 63303
PHONE: (314) 441-8086

November 24, 1992

U. S. Department of Energy
Weldon Spring Site Remedial Action Project
ATTN: Mr. Stephen H. McCracken
Project Manager
7295 Highway 94 South
St. Charles, MO 63304

SUBJECT: Contract No. DE-AC05-86OR21548
TRANSMITTAL OF SITE SOIL PERMEABILITY DATA TO THE MISSOURI DEPARTMENT OF NATURAL RESOURCES.

Dear Mr. McCracken:

Information from recent data gathering activities relating to permeability of undisturbed site soils is attached. This data was collected at the recommendation of the MDNR/DGLS technical staff, and relates to the technical requirements for hazardous waste landfill siting standards as presented in 10 CSR 25-7. Although this regulation is not considered applicable, we have agreed to utilize these requirements to develop design criteria, including the use of engineered fill to meet these standards. Specific data collected include:

- Laboratory permeability testing of undisturbed soils with both water and synthesized leachate as a permeant, performed to assess the effects of leachate on permeability.

- Field permeability testing of insitu site soils using a two-stage borehole (TSB) procedure.

General conclusions from these data are as follows:

- Results of TSB testing indicate that *in situ* hydraulic conductivity is not affected by macropore features such as cracks or fractures.

- Logarithmic mean field permeability values (TSB results) range from 1.28 E^{-08} to 3.34 E^{-09} (cm/s).

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- Hydraulic conductivity values obtained under recent efforts are consistent with prior data, and support the suitability of the proposed area for a disposal site.

- Synthesized leachate has no detectable effect on permeability. Logarithmic mean hydraulic conductivity values range from 1.26 E^{-09} cm/s (leachate) to 1.66 E^{-09} cm/s (water).

- These values indicate that a 20 ft layer of site clay soils will retard the migration of hazardous constituents contained in the waste to at least the same degree that 30 ft of material having a coefficient of permeability of 1.0 E^{-07} cm/s would retard the migration of water.

A technical memorandum is attached that includes data interpretation, data tables, technical references, example calculations, and graphical presentations of the data. A formal report will be forthcoming.

Please transmit this information to the MDNR and the EPA. A draft letter of transmittal is included for your use. A copy of this letter with attachments will be placed into the administrative record. Please contact Rick Ferguson or Ken Warbritton of my staff should you have any questions.

Sincerely,

James R. Powers

James R. Powers
Project Director

JRP/krw/kem

Attachment

cc: Walker K. Love

Department of Energy
Oak Ridge Operations
Weldon Spring Site
Remedial Action Project Office
7295 Highway 94 South
St. Charles, Missouri 63304

December 2, 1992

Dr. David E. Bedan
Division of Environmental Quality
Missouri Department of Natural Resources
Post Office Box 176
Jefferson City, Missouri 65102

Dear Dr. Bedan:

TRANSMITTAL OF SITE SOIL PERMEABILITY DATA

A technical memorandum from the Project Management Contractor (PMC) staff is enclosed for your information and review. This document outlines the results of recent data gathering activities relating to leachate permeability of site soils at the Weldon Spring Site. Specific data collected includes:

- Laboratory permeability testing of undisturbed soils with both water and synthesized leachate as a permeant, performed to assess the effects of leachate on permeability.
- Field permeability testing of insitu site soils using a two-state borehole (TSB) procedure.

General conclusions from this effort include:

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This information was collected at the request of the MDNR technical staff. A technical memorandum is enclosed that includes data interpretation, data tables, technical references, example calculations, and graphical presentations of the data. A formal report will be forthcoming.

If you have any questions please contact Ken Lawver of my staff at (314)441-8978.

Sincerely,

Jerry S. Van Fossen
Deputy Project Manager
Weldon Spring Site
Remedial Action Project

Enclosure:
As stated

cc w/enclosure:
Dan Wall, EPA
Mimi Garstang, MDNR-DGLS

MK-FERGUSON
A DIVISION OF
MORRISON KNUDSEN CORPORATION

INTER-OFFICE CORRESPONDENCE

DATE: November 23, 1992

TO: R. Ferguson

FROM: Kenyon Warbritton KRW/Jeff Carman JDC

SUBJECT: **TECHNICAL MEMORANDUM PRESENTING RESULTS OF RECENT LABORATORY AND FIELD PERMEABILITY TESTS.**

The PMC has recently completed Two-Stage Borehole (TSB) field permeability testing performed at the request of MDNR/DGLS personnel. These tests were performed on the Ferrelview Formation and clay till unit at locations within the Disposal Facility Study Area.

An additional testing program, triaxial permeability testing of small undisturbed samples, is nearly complete. These tests were performed using both water and a synthesized leachate as a permeant. This program is not yet finalized, however key findings are available at this time for review by interested parties.

Samples of these test programs were obtained in accordance with "Sampling Plan for Determination of Hydraulic Properties of Undisturbed Soils in the Weldon Spring Disposal Facility Study Area", Rev. 1, MK-JEG, Oct. 92. Data and conclusions from these two test programs, in addition to prior WSSRAP testing, were utilized to calculate travel times for water through a 20 ft. layer of site soil. These travel time values were compared to travel time values calculated for a 30 ft. layer of material with a hydraulic conductivity of 1.0 E^{-07} cm/s (as described in 10 CSR 25-7).

TWO-STAGE BOREHOLE FIELD PERMEABILITY TESTS

I. Please find the following attachments relating to the TSB test effort.

Attachment 1 - Figure indicating the locations of TSB tests.

Attachments 2A and 2B - Spreadsheet calculation summaries which yield initial temperature corrected hydraulic conductivity values for stage 1 (K1CT) and stage 2 (K2CT).

Attachments 3A and 3B - Plots of time versus hydraulic conductivity for stage 1 and stage 2.

Attachment 4A and 4B - Calculations of the final time-weighted average hydraulic conductivity (K1' and K2').

Attachment 5 - Spreadsheet calculation summary of the derived Kv and Kh values.

Attachment 6 - TSB Method Reference, "The STEI Two-Stage Borehole Field Permeability Test", Boutwell, March 1992.

II. Results of the TSB test program are summarized as follows:

- Table 1 provides a summary of TSB test results.

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Form 232-A 30M 8-87

- Table 2 provides a summary of basic statistics generated from the TSB results presented in Table 1.

- Results of TSB testing indicate that *in situ* hydraulic conductivity is not affected by macropore features such as cracks or fractures.

- TSB no. 9 exhibited the highest permeability and also exhibited some erratic behavior early in the testing program, leading PMC staff to question the integrity of this test boring. This data is presented and is utilized in the attached data summaries. PMC staff have recently added dye to the permeameter (TSB-9) to investigate potential leakage when abandoning this hole using controlled excavation.

WATER/LEACHATE PERMEABILITY TESTING

I. Please find the following attachments relating to water/leachate permeability testing:

Attachment 7 - Figure indicating locations for undisturbed site soil samples which were subjected to permeability testing (ASTM Method D-5084).

Attachment 8 - Summary of leachate synthesis methodology.

II. Results of the water/leachate permeability testing are summarized as follows:

- Table 3 summarizes the results to date of permeability tests run using water and leachate as a permeant.

- The effect of synthesized leachate on permeability values for these undisturbed soils was not detectable. Permeability values for two samples increased slightly, values for two samples decreased slightly, and values for two samples remained essentially the same when synthesized leachate was used as the permeant after tap water. These slight differences are within the range of accuracy obtained by test measurements.

CONCLUSIONS RESULTING FROM COMBINED DATA

I. Please find the following attachments relating to water/leachate permeability testing:

Attachment 9 - Presents calculations of travel time and permittivity which compare a 20 ft. thickness with hydraulic conductivity values from various WSSRAP sampling efforts (laboratory and field efforts) to a 30 ft. layer of soil with a hydraulic conductivity of 1.0 E^{-07} cm/s (per 10 CSR 25-7).

Attachment 10 - Presents a list of pertinent reference documents associated with the data and conclusions in this technical memorandum.

II. Conclusions resulting from review of combined data are summarized as follows:

Studies conducted to date have focuses on the hydrologic performance of site soils on a conservative basis. Geochemical performance studies focusing on leachate/mineral interaction are currently being negotiated with Pacific Northwest Laboratory (PNL). The hydrologic data presented herein are considered a "worst case" assessment of the material effects of leachate/mineral interaction.

- Field hydraulic conductivity testing by the Two-Stage Borehole method indicates that macropore features such as cracks and fractures do not result in larger hydraulic conductivity values than have previously been determined for the Ferrelview Formation and clay till soil units in the Disposal Facility Study Area.

- Laboratory triaxial permeability tests have shown synthesized leachate to have an undetectable effect on hydraulic conductivity of Ferrelview Formation and clay till soil unit samples.

- Travel time and permittivity calculations are used to demonstrate that the soil units comprising the foundation of the proposed disposal facility will provide a level of protection superior to the minimum criteria specified under 10 CSR 25-7.

- The data and calculations presented herein for the Ferrelview Formation and clay till soil units satisfy the criteria set forth under 10 CSR 25-7.264 (2)(N)1.A.(III) which addressed minimum soil performance requirements relative to the movement of hazardous constituents.

This information substantiates the suitability of the WSSRAP site for location of a disposal facility. A formal report regarding this data is forthcoming, pending completion of all associated testing. If you have any questions or comments, please contact K. Warbritton (ext. 3309) or J. Carman (ext. 3506).

cc (w/attach.):

S. Grozescu
R. Rager (MKE-BHO)
G. Nibler (MKE-BHO)
D. Daniel (UT)
D. Conover (MKE-BHO)
K. Lee (MKE-SFO)
J. Bognar
RC-22-26-3A

cc (w/o attach.):

K. Meyer
J. Williams
K. Greenwell
J. Meier
P. Cate

b:\mdnr.1

TABLE 1

SUMMARY OF HYDRAULIC CONDUCTIVITY
VALUES FROM
TWO-STAGE BOREHOLE TESTING

TSB NO.	Formation	K1′	K2′	Kv	Kh
TSB-01	FF	3.03 E^{-09}	2.80 E^{-09}	4.09 E^{-09}	2.25 E^{-09}
TSB-02	CT	3.04 E^{-09}	2.58 E^{-08}	9.11 E^{-10}	1.01 E^{-08}
TSB-03	FF	2.23 E^{-09}	3.19 E^{-09}	1.08 E^{-09}	4.58 E^{-09}
TSB-04	CT	3.05 E^{-09}	5.56 E^{-09}	9.14 E^{-10}	1.02 E^{-08}
TSB-05	CT	5.07 E^{-09}	1.69 E^{-09}	1.52 E^{-09}	1.69 E^{-08}
TSB-06	CT	4.12 E^{-09}	1.21 E^{-08}	1.24 E^{-09}	1.37 E^{-08}
TSB-07	FF	2.40 E^{-09}	1.48 E^{-09}	2.09 E^{-09}	2.75 E^{-09}
TSB-08	CT	4.00 E^{-09}	4.33 E^{-08}	1.20 E^{-09}	1.33 E^{-08}
TSB-09	FF	9.59 E^{-09}	1.67 E^{-07}	8.36 E^{-09}	1.10 E^{-08}
TSB-10	FF	6.06 E^{-09}	5.01 E^{-08}	8.18 E^{-09}	4.49 E^{-09}
TSB-11	CT	1.83 E^{-09}	1.34 E^{-08}	5.49 E^{-10}	6.10 E^{-09}
TSB-12	FF	1.85 E^{-09}	2.42 E^{-08}	2.50 E^{-09}	1.37 E^{-09}
TSB-13	CT	2.59 E^{-09}	5.22 E^{-08}	7.76 E^{-10}	8.64 E^{-09}

All hydraulic conductivity values are presented in units of cm/s.

K1′ = Arithmetic time-weighted average stage 1 hydraulic conductivity.

K2′ = Arithmetic time-weighted average stage 2 hydraulic conductivity.

Kv = Final calculated vertical component of hydraulic conductivity.

Kh = Final calculated horizontal component of hydraulic conductivity.

FF = Ferrelview Formation

CT = Clay Till unit

TABLE 2

TWO STAGE BOREHOLE TESTING STATISTICS

	K1′	K2′	Kv	Kh
Maximum K Value (FF)	9.59 E^{-09}	1.67 E^{-09}	8.36 E^{-09}	1.10 E^{-08}
Minimum K Value (FF)	1.85 E^{-09}	1.48 E^{-09}	1.08 E^{-09}	1.37 E^{-09}
Logarithmic Mean (FF)	3.47 E^{-09}	1.18 E^{-08}	3.41 E^{-09}	3.52 E^{-09}
Maximum K Value (CT)	5.07 E^{-09}	5.22 E^{-08}	1.20 E^{-09}	1.69 E^{-08}
Minimum K Value (CT)	1.83 E^{-09}	1.69 E^{-09}	5.49 E^{-10}	6.10 E^{-09}
Logarithmic Mean (CT)	3.23 E^{-09}	1.37 E^{-08}	9.69 E^{-10}	1.08 E^{-08}
Maximum K (Both Units)	9.59 E^{-09}	1.67 E^{-07}	8.36 E^{-09}	1.69 E^{-08}
Minimum K (Both Units)	1.83 E^{-09}	1.48 E^{-09}	5.49 E^{-10}	1.37 E^{-09}
Logarithmic Mean (Both Units)	3.34 E^{-09}	1.28 E^{-03}	1.73 E^{-09}	6.43 E^{-09}

All hydraulic conductivity values are presented in units of cm/s.

K1′ = Arithmetic time-weighted average stage 1 hydraulic conductivity.

K2′ = Arithmetic time-weighted average stage 2 hydraulic conductivity.

Kv = Final calculated vertical component of hydraulic conductivity.

Kh = Final calculated horizontal component of hydraulic conductivity.

FF = Ferrelview Formation

CT = Clay Till unit

TABLE 3

SUMMARY
OF
WATER/LEACHATE HYDRAULIC CONDUCTIVITY DATA

	Formation	Plasticity Index	Water K	Leachate K
GT80-ST12	CT	33	1.74 E^{-09}	1.22 E^{-09}
GT83-ST06	FF	44	1.25 E^{-09}	1.2 E^{-09}
GT83-ST12	CT	35	1.0 E^{-09}	1.2 E^{-09}
GT82-ST05	FF	60	5.0 E^{-10}	6.5 E^{-10}
GT82-ST08	CT	38	1.5 E^{-08}	2.68 E^{-09}
GT84-ST07	FF	61	1.3 E^{-09}	1.3 E^{-09}

Overall natural log mean hydraulic conductivity value for water is 1.66 E^{-09} cm/s.
Overall natural log mean hydraulic conductivity value for leachate is 1.26 E^{-09} cm/s.

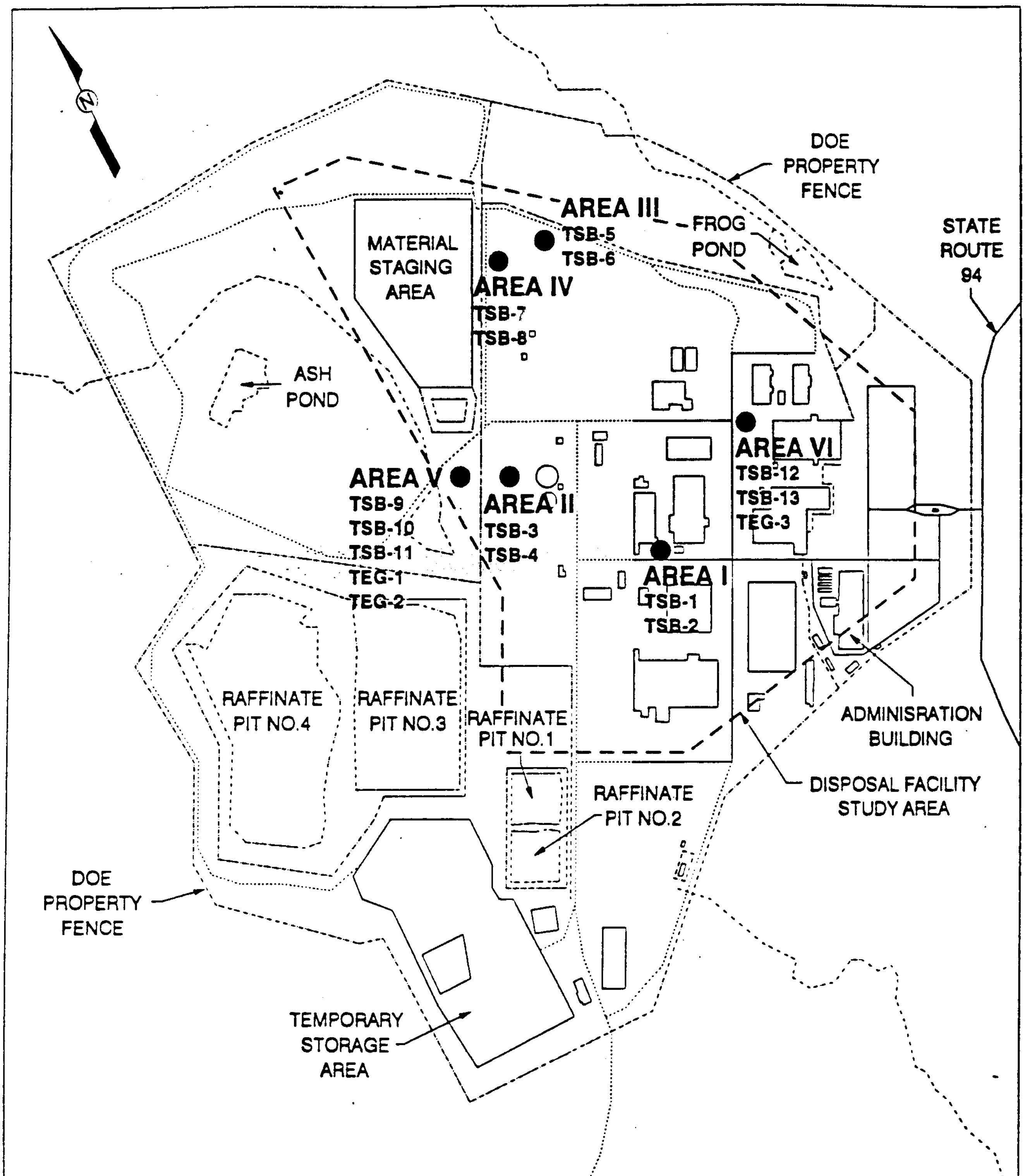
Sample ID	Formation	Days Water	Days Leachate	Water Pore Vol.	Leachate Pore Vol.	Total Pore Vol.
GT80-ST12	CT	5	38	0.18	0.70	0.88
GT83-ST06	FF	4	40	0.43	2.59	3.02
GT83-ST12	CT	7	23	0.53	1.79	2.32
GT82-ST05	FF	7	23	0.19	0.77	0.96
GT82-ST08	CT	8	16	3.53	3.91	7.44
GT84-ST07	FF	8	18	0.92	1.35	2.27

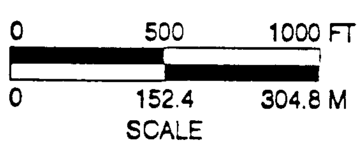
CT = Clay Till Soil Formation
FF = Ferrelview Clay Formation

Note: Values presented are current as of Nov. 16, 1992. Values for plasticity index are included for information. No correlations are proposed at this stage, relating PI to hydraulic conductivity. Hydraulic conductivity (K) values are shown in units of cm/s. Permeability testing with leachate will continue until all samples exceed 1.0 pore volume of leachate. Total pore volumes are estimated from calculations for total porosity for each sample.

ATTACHMENT 1

LOCATIONS OF TSB TESTS





TWO-STAGE BOREHOLE (TSB) PERMEABILITY TESTS LOCATION MAP

FIGURE 2-3

REPORT NO.:			EXHIBIT NO.:	A/CP/089/0692	
ORIGINATOR	SDG	DRAWN BY:	GLN	DATE	8/92

ATTACHMENT 2A

TSB
SPREADSHEET CALCULATION SUMMARY

STAGE 1 (K1')

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-1
Geometric factor-G=0.04030
Depth factor=239.12"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Ri	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1019	-	0.00	33.25	-	-	-	-	-	0	-	-	START
10/09	1215	6960	1.93	32.93	6.81E-09	-0.12	4.25E-09	1.1	4.68E-09	1.03	4.68E-09	-	
10/09	1359	6240	3.67	32.88	1.19E-09	0.00	1.19E-09	1.1	1.31E-09	1.19	3.08E-09	41%	
10/09	1624	8700	6.08	31.75	1.93E-08	0.00	1.93E-08	1.1	2.12E-08	4.82	1.03E-08	108%	
10/10	822	57480	22.05	14.00	4.75E-08	-0.12	4.72E-08	1.1	5.19E-08	61.64	4.04E-08	119%	
10/10	1600	13080	25.68	12.50	1.83E-08	-0.19	1.60E-08	1.1	1.76E-08	66.66	3.72E-08	8%	
10/10	1601	14460	29.70	12.13	4.10E-09	0.06	4.77E-09	1.1	5.24E-09	67.65	3.29E-08	12%	
10/10	1605	240	29.77	35.31	4.10E-09	0.00	4.77E-09	1.1	5.25E-09	67.65	3.28E-08	0%	Refill
10/11	809	57840	45.83	20.75	3.80E-08	-0.12	3.77E-08	1.1	4.14E-08	114.62	3.58E-08	9%	
10/11	1133	12240	49.23	19.13	2.06E-08	-0.19	1.82E-08	1.1	2.00E-08	119.83	3.47E-08	3%	
10/11	1555	15720	53.60	17.88	1.24E-08	0.06	1.30E-08	1.1	1.43E-08	123.84	3.31E-08	5%	
10/11	1558	180	53.65	33.75	1.24E-08	0.00	1.30E-08	1.1	1.43E-08	123.84	3.31E-08	0%	Refill
10/12	750	57120	69.52	25.25	2.23E-08	-0.06	2.22E-08	1.1	2.44E-08	151.15	3.11E-08	6%	
10/12	1153	14580	73.57	23.31	2.04E-08	-0.19	1.84E-08	1.1	2.02E-08	157.38	3.05E-08	2%	
10/12	1535	13320	77.27	22.50	9.35E-09	0.12	1.07E-08	1.1	1.18E-08	159.98	2.98E-08	3%	
10/13	743	58080	93.40	18.81	9.86E-09	-0.12	9.53E-09	1.1	1.05E-08	171.83	2.63E-08	12%	
10/13	1705	33720	102.77	17.38	6.84E-09	-0.31	5.20E-09	1.1	5.72E-09	176.43	2.44E-08	7%	
10/14	819	54840	118.00	14.63	7.92E-09	0.06	8.09E-09	1.1	8.90E-09	185.26	2.24E-08	9%	
10/14	1600	27660	125.68	14.25	2.18E-09	0.36	4.37E-09	1.1	4.81E-09	186.46	2.13E-08	5%	
10/15	855	60900	142.60	10.50	9.87E-09	-0.50	6.54E-09	1.1	9.40E-09	198.53	1.99E-08	7%	
10/15	1356	18060	147.62	10.12	3.40E-09	0.12	4.47E-09	1.1	4.92E-09	199.75	1.94E-08	3%	
10/16	806	65400	165.78	7.75	5.89E-09	-0.12	5.59E-09	1.1	6.15E-09	207.36	1.80E-08	8%	
10/16	1623	29820	174.07	6.88	4.77E-09	-0.07	4.39E-09	1.1	4.83E-09	210.16	1.73E-08	4%	
10/17	847	59040	190.47	5.50	3.84E-09	0.00	3.84E-09	1.1	4.22E-09	214.59	1.62E-08	7%	
10/18	928	88860	215.15	3.69	3.37E-09	-0.06	3.26E-09	1.1	3.58E-09	220.41	1.48E-08	9%	
10/18	929	60	215.17	33.00	3.37E-09	0.00	3.26E-09	1.1	3.59E-09	220.41	1.48E-08	0%	Refill
10/19	921	85980	239.05	23.25	1.71E-08	0.00	1.71E-08	1.1	1.88E-08	251.73	1.52E-08	3%	
10/19	1630	25740	246.20	21.63	9.70E-09	-0.06	9.34E-09	1.1	1.03E-08	256.94	1.50E-08	1%	
10/20	1635	86700	270.28	17.13	8.09E-09	-0.25	7.64E-09	1.1	8.40E-09	271.39	1.44E-08	4%	
10/21	1635	86400	294.28	14.88	4.11E-09	-0.06	4.00E-09	1.1	4.40E-09	278.62	1.36E-08	6%	
10/22	1700	87900	318.70	13.13	3.17E-09	0.00	3.17E-09	1.1	3.49E-09	284.24	1.28E-08	6%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-1
Geometric factor-G=0.04030
Depth factor=239.12"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/23	1637	85020	342.32	11.50	3.07E-09	0.00	3.07E-09	1.1	3.38E-09	289.48	1.22E-08	5%	
10/24	1533	82560	365.25	9.94	3.05E-09	0.00	3.05E-09	1.1	3.35E-09	294.49	1.18E-08	5%	
10/25	1555	91320	390.62	8.89	2.22E-09	-0.31	1.67E-09	1.1	1.84E-09	298.50	1.10E-08	6%	+1 Hr Daylight
10/28	1310	76500	411.87	7.50	2.54E-09	-0.50	1.47E-09	1.1	1.62E-09	302.33	1.05E-08	5%	Savings Time

END OF TEST TSB-1

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-2
Geometric factor-G=0.04030
Depth factor=358.75"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1020	-	0.00	33.12	-	-	-	-	-	0.00	-	-	START
10/09	1216	6960	1.93	31.81	1.94E-08	-0.12	1.76E-08	1.1	1.94E-08	4.21	1.94E-08	-	
10/09	1400	6240	3.67	31.31	8.27E-09	0.00	8.27E-09	1.1	9.10E-09	5.81	1.45E-08	29%	
10/09	1624	8640	6.07	30.81	5.98E-09	0.00	5.98E-09	1.1	6.58E-09	7.42	1.14E-08	24%	
10/10	823	57540	22.05	28.06	4.96E-09	-0.12	4.74E-09	1.1	5.22E-09	16.25	5.91E-09	49%	
10/10	952	5340	23.53	27.69	7.22E-09	-0.19	3.51E-09	1.1	3.86E-09	17.44	5.72E-09	3%	
10/10	955	180	23.58	32.75	7.22E-09	0.00	3.51E-09	1.1	3.86E-09	17.44	5.71E-09	0%	
10/10	1201	7560	25.68	32.44	4.22E-09	-0.19	1.63E-09	1.1	1.80E-09	67.65	6.31E-09	6%	
10/10	1607	14760	29.78	32.00	3.07E-09	0.06	3.49E-09	1.1	3.84E-09	69.26	5.97E-09	6%	
10/11	810	57780	45.83	29.83	4.24E-09	-0.12	4.03E-09	1.1	4.43E-09	76.66	5.43E-09	9%	
10/11	1134	12240	49.23	29.06	4.84E-09	-0.19	3.22E-09	1.1	3.55E-09	78.71	5.30E-09	2%	
10/11	1559	15900	53.65	28.81	1.63E-09	0.06	2.03E-09	1.1	2.23E-09	123.84	5.05E-09	5%	
10/12	751	57120	69.52	28.88	3.52E-09	-0.06	3.41E-09	1.1	3.75E-09	130.04	4.75E-09	6%	
10/12	1153	14520	73.55	26.31	4.11E-09	-0.19	2.74E-09	1.1	3.01E-09	131.87	4.66E-09	2%	
10/12	1536	13380	77.27	26.30	7.82E-11	0.12	1.02E-09	1.1	1.12E-09	131.90	4.49E-09	4%	
10/13	744	58080	93.40	24.25	3.70E-09	-0.12	3.49E-09	1.1	3.84E-09	138.49	4.38E-09	3%	
10/13	1706	33720	102.77	23.62	1.97E-09	-0.31	9.99E-10	1.1	1.10E-09	140.51	4.08E-09	7%	
10/14	819	54780	117.98	21.75	3.61E-09	0.06	3.72E-09	1.1	4.09E-09	146.52	4.08E-09	0%	
10/14	1602	27780	125.70	22.00	9.53E-10	0.38	4.96E-10	1.1	5.45E-10	145.72	3.86E-09	5%	
10/15	854	60720	142.57	19.81	3.83E-09	-0.50	2.95E-09	1.1	3.25E-09	152.75	3.79E-09	2%	
10/15	1357	18180	147.62	19.69	7.03E-10	0.12	1.41E-09	1.1	1.55E-09	153.14	3.71E-09	2%	
10/16	807	65400	165.78	17.50	3.58E-09	-0.12	3.38E-09	1.1	3.72E-09	160.17	3.71E-09	0%	
10/16	1624	29820	174.07	16.50	3.80E-09	-0.07	3.34E-09	1.1	3.68E-09	163.39	3.71E-09	0%	
10/17	846	58920	190.43	14.75	3.20E-09	0.00	3.20E-09	1.1	3.52E-09	169.01	3.69E-09	0%	
10/18	930	89040	215.17	12.02	3.32E-09	-0.06	3.25E-09	1.1	3.57E-09	177.78	3.68E-09	0%	
10/19	920	85800	239.00	9.88	2.72E-09	0.00	2.72E-09	1.1	2.99E-09	184.65	3.61E-09	2%	
10/19	1630	25800	246.17	9.25	2.67E-09	-0.06	2.42E-09	1.1	2.66E-09	186.68	3.58E-09	1%	
10/20	1637	86820	270.28	7.00	2.85E-09	-0.25	2.53E-09	1.1	2.78E-09	193.90	3.51E-09	2%	
10/21	1635	86280	294.25	5.13	2.39E-09	-0.06	2.32E-09	1.1	2.55E-09	199.91	3.43E-09	2%	
10/21	1640	300	294.33	34.81	2.39E-09	0.00	2.32E-09	1.1	2.55E-09	199.91	3.43E-09	0%	Refill
10/22	1701	87660	318.68	32.31	2.93E-09	0.00	2.93E-09	1.1	3.22E-09	207.94	3.42E-09	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-2
Geometric factor-G=0.04030
Depth factor=358.75"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/23	1640	85140	342.33	29.88	2.95E-09	-	2.95E-09	1.1	3.25E-09	215.75	3.41E-09	0%	RTEG 3 Temp
10/24	1535	82500	365.25	27.38	3.15E-09	-	3.15E-09	1.1	3.47E-09	223.78	3.41E-09	0%	Stabilizing
10/25	1558	91380	390.63	25.13	2.58E-09	-0.37	2.15E-09	1.1	2.37E-09	231.01	3.34E-09	2%	+1 Hr Daylight
10/26	1308	76200	411.80	22.94	3.03E-09	0.12	3.19E-09	1.1	3.51E-09	238.04	3.35E-09	0%	Savings Time

END OF TEST TSB-2

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-3
Geometric factor-G=0.04030
Depth factor=162.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1515	0	0.00	32.81.	-	-	-	-	-	0.00	-	-	START
10/09	1620	3900	1.08	32.75	3.18E-09	0.00	3.18E-09	1.1	3.50E-09	0.19	3.50E-09	-	
10/10	825	57900	17.17	30.13	9.42E-09	-0.13	8.94E-09	1.1	9.84E-09	8.81	9.44E-09	92%	
10/10	1207	13320	20.87	29.38	1.18E-08	-0.18	8.98E-09	1.1	9.88E-09	11.02	9.52E-09	1%	
10/10	1810	14580	24.92	29.13	3.81E-09	0.12	5.34E-09	1.1	5.88E-09	11.82	8.92E-09	6%	
10/11	814	57840	40.98	27.00	7.80E-09	-0.25	6.88E-09	1.1	7.57E-09	18.66	8.39E-09	6%	
10/11	1137	12180	44.37	26.56	7.70E-09	-0.19	4.37E-09	1.1	4.81E-09	20.08	8.12E-09	3%	
10/11	1603	15960	48.80	26.50	8.03E-10	0.12	2.41E-09	1.1	2.65E-09	20.27	7.62E-09	6%	
10/12	753	57000	64.63	24.88	6.09E-09	0.00	6.09E-09	1.1	6.70E-09	25.47	7.40E-09	3%	
10/12	1200	14820	68.75	24.63	3.64E-09	-0.32	6.09E-09	1.1	6.70E-09	26.26	7.36E-09	1%	
10/12	1538	13080	72.38	24.75	3.84E-09	0.19	1.15E-09	1.1	1.27E-09	25.89	7.05E-09	4%	
10/13	747	58140	88.53	23.13	6.03E-09	-0.12	5.58E-09	1.1	6.14E-09	31.10	6.88E-09	2%	
10/13	1655	32880	97.67	23.13	6.03E-09	0.06	3.97E-10	1.1	4.36E-10	31.10	6.26E-09	9%	
10/14	826	55860	113.18	22.00	4.41E-09	-0.25	3.43E-09	1.1	3.78E-09	34.73	5.94E-09	6%	
10/14	1609	27780	120.90	22.63	4.41E-09	0.43	3.43E-09	1.1	3.77E-09	32.70	5.80E-09	2%	
10/15	826	59820	137.52	21.00	5.97E-09	-0.50	4.13E-09	1.1	4.54E-09	37.94	5.65E-09	3%	
10/15	1402	18960	142.78	21.06	5.94E-09	0.06	4.11E-09	1.1	4.52E-09	37.75	5.61E-09	1%	
10/16	811	65340	160.93	19.62	4.86E-09	-0.06	4.66E-09	1.1	5.13E-09	42.37	5.55E-09	1%	
10/16	1629	29880	169.23	19.06	4.16E-09	0.00	4.16E-09	1.1	4.58E-09	44.17	5.50E-09	1%	
10/17	842	58380	185.45	17.86	4.51E-09	0.06	4.74E-09	1.1	5.21E-09	47.96	5.48E-09	0%	
10/18	924	88920	210.15	16.13	4.42E-09	0.00	4.42E-09	1.1	4.87E-09	53.58	5.41E-09	1%	
10/19	1635	112260	241.33	14.31	3.66E-09	-0.13	3.42E-09	1.1	3.76E-09	59.43	5.19E-09	4%	
10/20	1640	86700	265.42	13.00	3.46E-09	-0.25	2.80E-09	1.1	3.08E-09	63.64	5.00E-09	4%	
10/21	1643	86580	289.47	12.25	2.00E-09	0.13	2.34E-09	1.1	2.58E-09	66.05	4.80E-09	4%	
10/22	1704	87660	313.82	11.50	1.98E-09	0.00	1.98E-09	1.1	2.18E-09	68.46	4.60E-09	4%	
10/23	1642	85080	337.45	10.69	2.21E-09	0.00	2.21E-09	1.1	2.43E-09	71.06	4.45E-09	3%	
10/24	1543	82860	360.47	9.50	3.36E-09	0.00	3.36E-09	1.1	3.69E-09	74.88	4.40E-09	1%	
10/25	1600	91020	385.75	8.88	1.60E-09	-0.31	8.00E-10	1.1	8.80E-10	76.87	4.17E-09	5%	+1 Hr Daylight
10/26	1510	83400	408.92	7.88	2.83E-09	-0.44	1.58E-09	1.1	1.74E-09	80.09	4.03E-09	3%	Savings Time

END OF TEST TSB-3

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSD-4
Geometric factor-G=0.04030
Depth factor=239.25"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1516	0	0.00	34.25	-	-	-	-	-	0.00	-	-	START
10/09	1620	3840	1.07	34.06	7.29E-09	0.00	7.29E-09	1.1	8.02E-09	0.61	8.02E-09	-	
10/10	826	57960	17.17	32.13	4.93E-09	-0.12	4.62E-09	1.1	5.08E-09	6.81	5.26E-09	42%	
10/10	1208	13320	20.87	31.81	3.57E-09	-0.19	1.45E-09	1.1	1.59E-09	7.84	4.61E-09	13%	
10/10	1612	14640	24.93	31.75	6.09E-10	0.06	1.22E-09	1.1	1.34E-09	8.03	4.06E-09	12%	
10/11	815	57780	40.98	30.50	3.22E-09	-0.12	2.91E-09	1.1	3.21E-09	12.05	3.74E-09	9%	
10/11	1138	12180	44.37	30.13	4.54E-09	-0.19	2.21E-09	1.1	2.43E-09	17.44	3.64E-09	3%	
10/11	1604	15960	48.80	30.06	6.56E-10	0.06	1.22E-09	1.1	1.34E-09	67.65	3.43E-09	6%	
10/12	754	57000	64.63	29.13	2.45E-09	-0.06	2.29E-09	1.1	2.52E-09	70.84	3.21E-09	7%	
10/12	1200	14760	68.73	28.81	3.26E-09	-0.19	1.32E-09	1.1	1.46E-09	71.87	3.10E-09	3%	
10/13	748	71280	88.53	28.00	1.71E-09	0.00	1.71E-09	1.1	1.88E-09	74.47	2.63E-09	9%	
10/14	825	88620	113.15	26.75	2.13E-09	-0.25	1.70E-09	1.1	1.86E-09	78.48	2.82E-09	6%	
10/15	845	87600	137.48	14.13	2.24E-08	-0.12	2.21E-08	1.1	2.44E-08	119.02	6.47E-09	65%	
10/15	1401	18960	142.75	13.88	2.10E-09	0.12	3.11E-09	1.1	3.42E-09	119.83	6.36E-09	2%	
10/15	1442	60	142.77	34.75	2.10E-09	0.00	3.11E-09	1.1	3.42E-09	119.83	6.36E-09	0%	Refill
10/16	810	62880	160.23	31.25	8.24E-09	-0.12	7.96E-09	1.1	8.75E-09	131.07	6.62E-09	4%	
10/16	1627	29820	168.52	30.12	5.66E-09	-0.07	5.31E-09	1.1	5.84E-09	134.70	6.56E-09	1%	
10/17	841	58440	184.75	28.25	4.80E-09	0.00	4.80E-09	1.1	5.28E-09	140.71	6.46E-09	2%	
10/18	925	89040	209.48	25.69	4.35E-09	-0.06	4.25E-09	1.1	4.67E-09	148.93	6.25E-09	3%	
10/19	932	86820	233.60	23.31	4.19E-09	0.00	4.19E-09	1.1	4.61E-09	156.56	6.06E-09	3%	
10/19	1634	25320	240.63	22.69	3.76E-09	-0.06	3.40E-09	1.1	3.74E-09	158.57	6.01E-09	1%	
10/20	1642	86880	264.77	20.69	3.56E-09	-0.25	3.11E-09	1.1	3.42E-09	165.00	5.78E-09	4%	
10/21	1644	86520	288.80	19.00	3.04E-09	-0.06	2.93E-09	1.1	3.22E-09	170.43	5.57E-09	4%	
10/22	1705	87660	313.15	17.31	3.02E-09	0.00	3.02E-09	1.1	3.32E-09	175.85	5.39E-09	3%	
10/23	1645	85200	336.82	15.63	3.11E-09	0.00	3.11E-09	1.1	3.42E-09	181.25	5.25E-09	3%	
10/24	1545	82800	359.82	13.94	3.24E-09	0.00	3.24E-09	1.1	3.56E-09	186.66	5.14E-09	2%	
10/25	1602	91020	385.10	12.38	2.74E-09	-0.31	2.19E-09	1.1	2.41E-09	191.69	4.96E-09	4%	+1 Hr Daylight
10/26	1504	82920	408.13	10.75	3.16E-09	-0.50	2.19E-09	1.1	2.41E-09	196.93	4.82E-09	3%	Savings Time

END OF TEST TSD-4

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSD-5
Geometric factor-G=0.04534
Depth factor=153.5"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/10	853	0	0.00	33.50	-	-	-	-	-	0.00	-	-	START
10/10	1232	13140	3.65	33.13	6.83E-09	-0.18	3.51E-09	1.1	3.86E-09	1.19	3.86E-09	-	
10/10	1636	14640	7.72	33.06	1.16E-09	0.12	3.15E-09	1.1	3.47E-09	1.41	3.65E-09	5%	
10/11	833	57420	23.67	30.25	1.20E-08	-0.25	1.09E-08	1.1	1.20E-08	10.44	9.28E-09	87%	
10/11	1159	12360	27.10	29.69	1.12E-08	-0.19	7.39E-09	1.1	8.13E-09	12.24	9.13E-09	2%	
10/11	1608	14940	31.25	29.56	2.15E-09	0.12	4.14E-09	1.1	4.56E-09	12.66	8.53E-09	7%	
10/12	758	57000	47.08	28.94	1.15E-08	0.00	1.15E-08	1.1	1.26E-08	21.07	9.90E-09	15%	
10/12	1203	14700	51.17	28.25	1.18E-08	-0.32	8.33E-09	1.1	8.96E-09	23.29	9.67E-09	2%	
10/12	1541	13080	54.80	26.13	2.31E-09	0.19	5.98E-09	1.1	6.58E-09	23.66	9.46E-09	2%	
10/13	751	58200	70.97	23.56	1.12E-08	-0.12	1.07E-08	1.1	1.18E-08	31.93	9.99E-09	5%	
10/13	1641	31800	79.80	22.81	6.05E-09	0.06	6.54E-09	1.1	7.19E-09	34.34	9.68E-09	3%	
10/14	853	58320	96.00	20.88	8.56E-09	-0.25	7.44E-09	1.1	8.19E-09	40.54	9.43E-09	3%	
10/14	1638	27900	103.75	21.25	-3.4E-09	0.43	5.59E-10	1.1	6.15E-10	39.36	8.77E-09	7%	
10/15	830	57120	119.62	19.00	1.03E-08	-0.50	7.99E-09	1.1	8.79E-09	46.56	8.77E-09	0%	
10/15	1416	20760	125.38	18.75	3.17E-09	0.06	3.93E-09	1.1	4.32E-09	47.36	8.57E-09	2%	
10/16	827	65460	143.57	16.88	7.56E-09	-0.06	7.32E-09	1.1	8.05E-09	53.39	8.50E-09	1%	
10/16	1642	29700	151.82	16.25	5.86E-09	0.00	5.86E-09	1.1	6.22E-09	55.41	8.38E-09	1%	
10/17	825	56580	167.53	14.81	6.83E-09	0.06	7.11E-09	1.1	7.82E-09	60.04	8.32E-09	1%	
10/18	857	88320	192.07	12.88	5.92E-09	0.00	5.92E-09	1.1	6.51E-09	66.24	8.09E-09	3%	
10/19	952	89700	216.98	11.00	5.74E-09	0.19	6.33E-09	1.1	6.96E-09	72.28	7.96E-09	2%	
10/19	1650	25080	223.95	10.56	4.84E-09	-0.13	3.41E-09	1.1	3.75E-09	73.69	7.83E-09	2%	
10/20	1650	86400	247.95	9.00	5.01E-09	-0.25	4.21E-09	1.1	4.63E-09	78.70	7.52E-09	4%	
10/21	1648	86280	271.92	7.94	3.44E-09	0.13	3.86E-09	1.1	4.25E-09	82.11	7.23E-09	4%	
10/22	1709	87660	296.27	6.81	3.63E-09	0.00	3.63E-09	1.1	4.00E-09	85.74	6.97E-09	4%	
10/23	1647	85080	319.90	5.56	4.17E-09	0.00	4.17E-09	1.1	4.59E-09	89.76	6.79E-09	3%	
10/23	1650	180	343.58	34.00	4.17E-09	0.00	4.17E-09	1.1	4.59E-09	89.76	6.79E-09	0%	Refill
10/24	1546	82680	366.55	31.50	7.36E-09	0.00	7.36E-09	1.1	8.10E-09	97.79	6.44E-09	5%	
10/25	1605	91020	391.83	29.88	4.38E-09	-0.31	3.54E-09	1.1	3.89E-09	103.00	6.27E-09	3%	+1 Hr Daylight
10/26	1625	87600	416.17	28.13	4.96E-09	-0.44	3.71E-09	1.1	4.08E-09	108.62	6.14E-09	2%	Savings Time
10/27	805	56400	431.83	27.06	4.75E-09	0.06	5.02E-09	1.1	5.52E-09	112.05	6.12E-09	0%	
10/27	1110	11100	434.92	26.75	7.02E-09	-0.19	2.72E-09	1.1	2.99E-09	113.05	6.10E-09	0%	END OF TEST TS

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSD-6
Geometric factor-G=0.04534
Depth factor=231.5"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	KI	TC	KIC	visc. factor	KICT	cumulative volume (cc)	K (twa)	RPD (KIwa)	Comments
10/10	923	0	0.00	33.62	-	-	-	-	-	0.00	-	-	START
10/10	959	2160	0.60	33.00	4.91E-08	0.00	4.91E-08	1.1	5.41E-08	1.99	5.41E-08	-	
10/10	1234	9300	3.18	31.31	3.13E-08	-0.19	2.77E-08	1.1	3.05E-08	7.42	3.49E-08	43%	
10/10	1638	14640	7.25	29.88	1.69E-08	0.06	1.76E-08	1.1	1.94E-08	12.01	2.62E-08	29%	
10/11	832	57240	23.15	26.50	1.03E-08	-0.12	9.94E-09	1.1	1.09E-08	22.87	1.57E-08	50%	
10/11	1200	12480	26.62	26.06	6.20E-09	-0.19	3.52E-09	1.1	3.87E-09	24.29	1.42E-08	10%	
10/11	1609	14940	30.77	25.88	2.12E-09	0.06	2.83E-09	1.1	3.11E-09	24.86	1.27E-08	11%	
10/12	759	57000	46.60	23.25	8.17E-09	-0.06	7.98E-09	1.1	8.78E-09	33.31	1.14E-08	11%	
10/12	1204	14700	50.68	22.88	4.46E-09	-0.19	2.18E-09	1.1	2.40E-09	34.50	1.06E-08	7%	
10/12	1542	13080	54.32	22.81	9.54E-10	0.12	2.59E-09	1.1	2.85E-09	34.73	1.01E-08	5%	
10/13	752	58200	70.48	20.25	7.86E-09	-0.12	7.51E-09	1.1	8.26E-09	42.95	9.69E-09	4%	
10/13	1643	31860	79.33	19.75	2.83E-09	-0.31	1.07E-09	1.1	1.18E-09	44.56	8.74E-09	10%	
10/14	854	58280	95.52	17.62	6.63E-09	0.06	6.81E-09	1.1	7.49E-09	51.40	8.53E-09	2%	
10/14	1639	27900	103.27	17.94	6.63E-09	0.38	3.91E-10	1.1	4.31E-10	50.37	7.92E-09	7%	
10/15	831	57120	119.13	15.63	7.39E-09	-0.50	5.78E-09	1.1	6.36E-09	57.79	7.71E-09	3%	
10/15	1416	20700	124.88	15.38	2.22E-09	0.12	3.28E-09	1.1	3.61E-09	58.59	7.52E-09	2%	
10/16	826	65400	143.05	13.00	8.72E-09	-0.12	6.38E-09	1.1	7.01E-09	66.24	7.46E-09	1%	
10/16	1627	29820	151.33	12.13	5.42E-09	-0.07	4.98E-09	1.1	5.48E-09	69.04	7.35E-09	1%	
10/17	841	56580	167.05	10.25	6.21E-09	0.00	6.21E-09	1.1	6.83E-09	75.07	7.30E-09	1%	
10/18	858	88320	191.58	7.94	4.93E-09	-0.06	4.80E-09	1.1	5.28E-09	82.50	7.04E-09	4%	
10/19	953	89700	216.50	5.50	5.18E-09	0.00	5.18E-09	1.1	5.70E-09	90.33	6.89E-09	2%	
10/19	953	0	216.50	31.44	5.18E-09	0.00	5.18E-09	1.1	5.70E-09	90.33	6.89E-09	0%	Refill
10/19	1650	25020	223.45	30.63	5.59E-09	-0.06	5.18E-09	1.1	5.69E-09	92.93	6.85E-09	1%	
10/20	1650	86400	247.45	28.31	4.67E-09	-0.25	4.16E-09	1.1	4.58E-09	100.38	6.63E-09	3%	
10/21	1651	86460	271.47	26.38	3.91E-09	-0.06	3.79E-09	1.1	4.17E-09	106.58	6.41E-09	3%	
10/22	1711	88824	296.14	24.38	3.97E-09	0.00	3.97E-09	1.1	4.37E-09	113.01	6.24E-09	3%	
10/23	1648	85020	319.76	22.38	4.18E-09	0.00	4.18E-09	1.1	4.60E-09	119.43	6.12E-09	2%	
10/24	1549	82860	342.77	20.50	4.07E-09	0.00	4.07E-09	1.1	4.47E-09	125.47	6.01E-09	2%	
10/25	1607	91080	368.07	18.50	3.97E-09	-0.31	3.35E-09	1.1	3.68E-09	131.90	5.85E-09	3%	+1 Hr Daylight
10/26	1627	87600	392.41	16.31	4.55E-09	-0.50	3.51E-09	1.1	3.86E-09	138.93	5.73E-09	2%	Savings Time

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-6
Geometric factor–G=0.04534
Depth factor=231.5"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	804	56220	408.02	14.88	4.87E-09	-0.25	3.85E-09	1.1	4.23E-09	143.53	5.87E-09	1%	
10/27	1125	12060	411.37	14.83	3.82E-09	-0.07	2.75E-09	1.1	3.02E-09	144.33	5.85E-09	0%	

END OF TEST TSB-6

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-7
Geometric factor–G=0.04534
Depth factor=161.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1112	0	0.00	33.50	–	–	–	–	–	0.00	–	–	START
10/09	1450	13080	3.63	33.31	3.38E-09	-0.06	1.98E-09	1.1	2.15E-09	0.61	2.16E-09	–	
10/10	836	63960	21.40	31.67	4.68E-09	-0.13	4.79E-09	1.1	5.27E-09	5.24	4.74E-09	75%	
10/10	1228	13929	25.27	31.63	3.58E-09	-0.18	1.01E-09	1.1	1.11E-09	6.01	4.18E-09	12%	
10/10	1632	14640	29.33	31.50	1.85E-09	0.12	4.02E-09	1.1	4.42E-09	6.42	4.22E-09	1%	
10/11	829	57420	45.28	30.25	4.54E-09	-0.25	4.11E-09	1.1	4.52E-09	10.44	4.32E-09	2%	
10/11	1141	11520	48.48	30.06	3.45E-09	-0.19	4.11E-09	1.1	4.52E-09	11.05	4.34E-09	0%	
10/11	1611	16200	52.98	29.94	1.55E-09	0.12	3.51E-09	1.1	3.86E-09	11.44	4.30E-09	1%	
10/12	800	56940	68.80	29.06	3.25E-09	0.00	3.67E-09	1.1	4.04E-09	14.26	4.24E-09	1%	
10/12	1205	14700	72.88	28.88	2.58E-09	-0.32	3.67E-09	1.1	4.04E-09	14.84	4.23E-09	0%	
10/12	1543	13080	76.52	28.88	2.58E-09	0.19	3.47E-09	1.1	3.81E-09	14.84	4.21E-09	0%	
10/13	754	58260	92.70	27.88	3.63E-09	-0.12	3.61E-09	1.1	3.97E-09	16.05	4.17E-09	1%	
10/13	1645	31860	101.55	27.75	8.65E-10	0.06	1.43E-09	1.1	1.57E-09	16.47	3.94E-09	6%	
10/14	850	57900	117.63	26.81	3.45E-09	-0.25	2.86E-09	1.1	3.15E-09	21.49	3.83E-09	3%	
10/14	1835	27900	125.38	27.19	3.45E-09	0.43	4.32E-10	1.1	4.75E-10	20.27	3.62E-09	6%	
10/15	834	57540	141.37	26.13	3.93E-09	-0.50	2.35E-09	1.1	2.58E-09	23.88	3.51E-09	3%	
10/15	1413	20340	147.02	26.06	7.38E-10	0.06	1.55E-09	1.1	1.70E-09	23.90	3.44E-09	2%	
10/16	823	65400	165.18	25.00	3.48E-09	-0.06	3.71E-09	1.1	4.08E-09	27.31	3.51E-09	2%	
10/16	1640	29820	173.47	24.82	2.75E-09	0.00	3.11E-09	1.1	3.42E-09	28.53	3.50E-09	0%	
10/17	831	57060	189.32	23.88	2.80E-09	0.06	3.43E-09	1.1	3.77E-09	30.90	3.53E-09	1%	
10/18	900	88140	213.80	22.75	2.78E-09	0.00	3.15E-09	1.1	3.46E-09	34.53	3.52E-09	0%	
10/19	950	89400	238.63	21.75	2.44E-09	0.19	3.29E-09	1.1	3.62E-09	37.75	3.53E-09	0%	
10/19	1645	24900	245.55	21.50	2.20E-09	-0.13	1.19E-09	1.1	1.31E-09	38.55	3.47E-09	2%	
10/20	1654	86940	269.70	20.56	2.38E-09	-0.25	1.97E-09	1.1	2.17E-09	41.57	3.35E-09	3%	
10/21	1654	86400	293.70	19.88	1.74E-09	0.13	2.34E-09	1.1	2.58E-09	43.75	3.29E-09	2%	
10/22	1713	87540	318.02	19.19	1.75E-09	0.00	1.98E-09	1.1	2.17E-09	45.97	3.20E-09	3%	
10/23	1655	85320	341.72	18.38	2.11E-09	–	2.39E-09	1.1	2.63E-09	48.57	3.16E-09	1%	
10/24	1552	82620	364.67	17.50	2.30E-09	0.19	3.28E-09	1.1	3.61E-09	51.40	3.19E-09	1%	
10/25	1608	90960	389.93	16.75	1.85E-09	-0.31	1.23E-09	1.1	1.35E-09	53.81	3.07E-09	4%	+1 Hr Daylight
10/26	1628	87600	414.27	15.75	2.58E-09	-0.44	1.63E-09	1.1	1.79E-09	57.02	3.00E-09	2%	Savings Time
10/27	807	56340	429.92	15.25	2.01E-09	0.06	2.55E-09	1.1	2.81E-09	58.63	2.99E-09	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-7
Geometric factor-G=0.04534
Depth factor=181.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	930	4980	431.30	15.25	0.00E+00	0.06	3.10E-09	1.1	3.41E-09	58.63	2.99E-09	0%	

END OF TEST TSB-7

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-8
Geometric factor-G=0.04534
Depth factor=237.0"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/09	1110	0	0.00	33.62	-	-	-	-	-	0.00	-	-	START
10/09	1456	13680	3.80	33.31	3.80E-09	0.00	3.80E-09	1.1	4.18E-09	1.00	4.18E-09	-	
10/10	837	63540	21.45	31.06	5.96E-09	0.00	5.96E-09	1.1	6.56E-09	8.22	6.14E-09	38%	
10/10	1229	13920	25.32	30.75	3.77E-09	-0.19	1.46E-09	1.1	1.60E-09	9.22	5.45E-09	12%	
10/10	1633	14640	29.38	29.63	1.30E-08	0.06	1.37E-08	1.1	1.50E-08	12.82	6.77E-09	22%	
10/11	830	57420	45.33	27.63	5.95E-09	-0.12	5.59E-09	1.1	6.15E-09	19.24	6.55E-09	3%	
10/11	1142	11520	48.53	27.31	4.76E-09	-0.19	1.93E-09	1.1	2.13E-09	20.27	6.26E-09	5%	
10/11	1612	16200	53.03	27.19	1.27E-09	0.06	1.91E-09	1.1	2.10E-09	20.66	5.91E-09	6%	
10/12	801	56940	68.85	25.88	3.96E-09	-0.06	3.78E-09	1.1	4.15E-09	24.86	5.51E-09	7%	
10/12	1206	14700	72.93	25.63	2.93E-09	-0.19	7.04E-10	1.1	7.74E-10	25.67	5.24E-09	5%	
10/12	1544	13080	76.57	25.69	-7.9E-10	0.12	7.92E-10	1.1	8.71E-10	25.47	5.03E-09	4%	
10/13	755	58260	92.75	24.38	3.89E-09	-0.12	3.53E-09	1.1	3.89E-09	29.68	4.83E-09	4%	
10/14	852	89820	117.70	23.06	2.56E-09	-0.25	2.07E-09	1.1	2.28E-09	33.92	4.29E-09	12%	
10/15	833	85260	141.38	22.06	2.05E-09	-0.12	1.80E-09	1.1	1.98E-09	37.14	3.90E-09	9%	
10/15	1414	20460	147.07	22.00	5.13E-10	0.12	1.54E-09	1.1	1.69E-09	37.33	3.82E-09	2%	
10/16	824	65400	165.23	20.31	4.54E-09	-0.12	4.22E-09	1.1	4.64E-09	42.76	3.91E-09	2%	
10/16	1640	29760	173.50	19.63	4.03E-09	-0.07	3.62E-09	1.1	3.98E-09	44.94	3.91E-09	0%	
10/17	830	57000	189.33	18.44	3.70E-09	0.00	3.70E-09	1.1	4.07E-09	48.76	3.93E-09	0%	
10/18	900	88200	213.83	16.88	3.15E-09	-0.06	3.03E-09	1.1	3.33E-09	53.78	3.86E-09	2%	
10/19	950	89400	238.67	15.38	3.01E-09	0.00	3.01E-09	1.1	3.31E-09	58.59	3.80E-09	1%	
10/19	1647	25020	245.62	15.00	2.73E-09	-0.06	2.30E-09	1.1	2.53E-09	59.82	3.76E-09	1%	
10/20	1655	86880	269.75	13.69	2.72E-09	-0.25	2.20E-09	1.1	2.42E-09	64.02	3.64E-09	3%	
10/21	1655	86400	293.75	11.19	5.26E-09	-0.06	5.13E-09	1.1	5.65E-09	72.06	3.81E-09	4%	
10/22	1715	87600	318.08	9.25	4.06E-09	0.00	4.06E-09	1.1	4.47E-09	78.29	3.86E-09	1%	
10/23	1657	85320	341,78	7.25	4.33E-09	-	4.33E-09	1.1	4.77E-09	84.71	3.92E-09	2%	
10/24	1548	82260	364.63	5.50	3.96E-09	-	3.96E-09	1.1	4.36E-09	90.33	3.95E-09	1%	
10/25	1610	91320	390.00	3.94	3.20E-09	-0.31	2.57E-09	1.1	2.82E-09	95.35	3.88E-09	2%	+1 Hr Daylight
10/26	1629	87540	414.32	2.00	4.19E-09	-0.50	3.10E-09	1.1	3.42E-09	101.58	3.85E-09	1%	Savings Time
10/26	1632	180	414.37	22.38	4.19E-09	0.00	3.10E-09	1.1	3.41E-09	101.58	3.85E-09	0%	Refill
10/27	806	56040	429.93	20.50	5.89E-09	-0.25	4.57E-09	1.1	5.03E-09	107.62	3.89E-09	1%	
10/27	930	5040	431.33	20.50	5.89E-09	-0.25	4.57E-09	1.1	5.03E-09	114.04	3.89E-09	0%	Repeat

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-9
Geometric factor-G=0.04030
Depth factor=160.0"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/07	836	0	0.00	35.25	–	–	–	–	–	0.00	–	–	START
10/07	1109	12780	3.55	35.30	-8.1E-10	–	-8.1E-10	1.1	-8.9E-10	-0.16	-8.88E-10	–	
10/07	1720	22260	9.73	35.20	9.27E-10	–	9.27E-10	1.1	1.02E-09	0.16	3.24E-10	-430%	
10/08	732	51120	23.93	33.75	5.88E-09	–	5.88E-09	1.1	6.47E-09	4.82	3.97E-09	170%	
10/08	1214	16920	28.63	33.19	6.89E-09	–	6.89E-09	1.1	7.58E-09	6.62	4.56E-09	14%	
10/08	1544	12600	32.13	32.81	6.30E-09	-0.05	5.47E-09	1.1	6.01E-09	7.84	4.72E-09	3%	
10/09	815	59460	48.65	30.94	6.61E-09	-0.38	5.28E-09	1.1	5.78E-09	13.85	5.08E-09	7%	
10/09	1005	6600	50.48	30.66	6.32E-09	-0.13	4.16E-09	1.1	4.57E-09	14.88	5.08E-09	0%	
10/09	1541	20160	56.08	30.25	4.51E-09	-0.08	3.67E-09	1.1	4.04E-09	16.06	4.98E-09	2%	
10/10	830	60540	72.90	28.12	7.49E-09	-0.13	7.03E-09	1.1	7.74E-09	22.90	5.60E-09	12%	
10/10	1220	13800	76.73	27.83	7.62E-09	-0.18	4.82E-09	1.1	5.30E-09	24.48	5.59E-09	0%	
10/10	1620	14400	80.73	27.38	3.73E-09	0.12	5.52E-09	1.1	6.08E-09	25.28	5.61E-09	0%	
10/11	824	57840	96.80	24.69	1.01E-08	-0.25	9.13E-09	1.1	1.00E-08	33.92	6.35E-09	12%	
10/11	1153	12540	100.28	24.25	7.67E-09	-0.19	4.35E-09	1.1	4.79E-09	35.34	6.29E-09	1%	
10/11	1623	16200	104.78	23.81	5.95E-09	0.12	7.57E-09	1.1	8.33E-09	36.75	6.36E-09	1%	
10/12	815	57120	120.65	21.50	6.92E-09	0.00	6.92E-09	1.1	9.82E-09	44.17	6.83E-09	7%	
10/12	1215	14400	124.65	21.00	7.72E-09	-0.32	2.78E-09	1.1	3.05E-09	45.78	6.71E-09	2%	
10/12	1553	13080	128.28	20.63	6.30E-09	0.19	9.55E-09	1.1	1.05E-08	46.97	6.82E-09	2%	
10/13	807	58440	144.52	18.19	9.38E-09	-0.12	8.91E-09	1.1	9.81E-09	54.80	7.15E-09	5%	
10/13	1702	32100	153.43	17.31	6.22E-09	0.06	6.64E-09	1.1	7.30E-09	57.63	7.16E-09	0%	
10/14	828	55560	168.87	15.06	9.28E-09	-0.25	8.23E-09	1.1	9.05E-09	64.86	7.33E-09	2%	
10/14	1612	27840	176.60	14.50	4.64E-09	0.43	8.21E-09	1.1	9.03E-09	66.66	7.41E-09	1%	
10/15	837	59100	193.02	11.88	1.03E-08	-0.49	8.37E-09	1.1	9.21E-09	75.07	7.56E-09	2%	
10/15	1409	19920	198.55	11.25	7.43E-09	0.06	8.14E-09	1.1	8.95E-09	77.10	7.60E-09	1%	
10/16	819	65400	216.72	8.63	9.50E-09	-0.08	9.28E-09	1.1	1.02E-08	85.52	7.82E-09	3%	
10/16	1636	29820	225.00	7.38	1.01E-08	0.00	1.01E-08	1.1	1.11E-08	89.53	7.94E-09	2%	
10/17	834	57480	240.97	5.12	9.53E-09	0.06	9.79E-09	1.1	1.08E-08	96.79	8.13E-09	2%	
10/18	905	88260	265.48	1.88	9.05E-09	0.00	9.05E-09	1.1	9.95E-09	107.20	8.30E-09	2%	
10/18	906	88320	290.02	33.81	9.05E-09	0.00	9.05E-09	1.1	9.05E-09	107.20	8.36E-09	1%	Refill
10/19	1642	113760	321.62	27.88	1.10E-08	-0.13	1.06E-08	1.1	1.18E-08	126.25	8.70E-09	4%	
10/20	1702	87600	345.95	23.94	9.75E-09	-0.25	9.13E-09	1.1	1.00E-08	136.91	8.79E-09	1%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-9
Geometric factor-G=0.04030
Depth factor=160.0"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	RI	KI	TC	KIC	visc. factor	KICT	cumulative volume (cc)	K (twa)	RPD (KIwa)	Comments
10/21	1707	86700	370.03	20.44	8.93E-09	0.13	9.26E-09	1.1	1.02E-08	150.15	8.89E-09	1%	
10/22	1728	87660	394.38	17.06	8.69E-09	0.00	8.69E-09	1.1	9.56E-09	161.01	8.93E-09	0%	
10/23	1710	85320	418.08	13.81	8.75E-09	-	8.75E-09	1.1	9.63E-09	171.45	8.97E-09	0%	
10/24	1610	82800	441.08	10.83	8.99E-09	-	8.99E-09	1.1	9.89E-09	181.66	9.02E-09	1%	
10/25	1625	90900	466.33	7.38	8.53E-09	-0.31	7.71E-09	1.1	8.48E-09	192.10	8.99E-09	0%	+1 Hr Daylight
10/26	1620	86100	490.25	4.13	9.18E-09	-0.44	7.92E-09	1.1	8.72E-09	202.55	8.97E-09	0%	Savings Time
10/26	1623	180	490.30	27.75	9.18E-09	0.00	7.92E-09	1.1	8.72E-09	202.55	8.97E-09	0%	Refill
10/27	813	57000	506.13	24.88	1.09E-08	0.06	1.11E-08	1.1	1.22E-08	211.77	9.07E-09	1%	

END OF TEST TSB-9

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-10
Geometric factor-G=0.04534
Depth factor=165.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/08	749	0	0.00	35.06	-	-	-	-	-	0.00	-	-	START
10/08	1032	9780	2.72	34.31	1.58E-08	-	1.58E-08	1.1	1.74E-08	2.41	1.74E-08	-	
10/08	1215	6180	4.43	33.56	2.51E-08	-	2.51E-08	1.1	2.76E-08	4.82	2.13E-08	20%	
10/08	1544	12540	7.92	33.00	9.27E-09	-0.05	8.44E-09	1.1	9.28E-09	6.62	1.80E-08	28%	
10/09	816	59520	24.45	30.31	9.45E-09	-0.38	8.11E-09	1.1	8.92E-09	15.26	1.12E-08	35%	
10/09	1008	6600	26.28	30.00	9.89E-09	-0.13	5.74E-09	1.1	6.31E-09	16.25	1.09E-08	3%	
10/09	1542	20160	31.88	29.44	5.86E-09	-0.08	5.02E-09	1.1	5.52E-09	18.05	9.94E-09	9%	
10/10	831	60540	48.70	27.00	8.56E-09	-0.13	8.10E-09	1.1	8.91E-09	25.89	9.58E-09	4%	
10/10	1222	13860	52.55	26.63	5.71E-09	-0.18	2.93E-09	1.1	3.22E-09	27.08	9.12E-09	5%	
10/10	1622	14400	56.55	26.25	5.65E-09	0.12	7.44E-09	1.1	8.18E-09	28.30	9.05E-09	1%	
10/11	825	57760	72.60	23.75	9.33E-09	-0.25	8.39E-09	1.1	9.23E-09	36.33	9.09E-09	0%	
10/11	1154	12540	76.08	23.31	7.62E-09	-0.19	4.33E-09	1.1	4.76E-09	37.75	8.89E-09	2%	
10/11	1624	16200	80.58	23.06	3.36E-09	0.12	4.97E-09	1.1	5.47E-09	38.55	8.70E-09	2%	
10/12	816	57120	96.45	20.88	8.35E-09	0.00	8.35E-09	1.1	9.19E-09	45.55	8.76E-09	1%	
10/12	1216	14400	100.45	20.44	8.73E-09	-0.32	1.83E-09	1.1	2.02E-09	46.97	8.51E-09	3%	
10/12	1553	13020	104.07	20.38	1.02E-09	0.19	4.24E-09	1.1	4.66E-09	47.18	8.38E-09	2%	
10/13	807	58440	120.30	18.06	8.80E-09	-0.12	8.35E-09	1.1	9.18E-09	54.81	8.49E-09	1%	
10/13	1700	31980	129.18	17.75	2.18E-09	0.06	2.58E-09	1.1	2.84E-09	55.81	8.10E-09	5%	
10/14	832	55920	144.72	15.75	8.03E-09	-0.25	7.02E-09	1.1	7.72E-09	62.03	8.06E-09	1%	
10/14	1632	28800	152.72	16.00	-2.0E-09	0.43	1.41E-09	1.1	1.55E-09	61.23	7.72E-09	4%	
10/15	838	57960	168.82	13.56	9.54E-09	-0.49	7.62E-09	1.1	8.38E-09	69.07	7.78E-09	1%	
10/15	1408	19800	174.32	13.38	2.07E-09	0.06	2.77E-09	1.1	3.04E-09	69.65	7.63E-09	2%	
10/16	818	65400	192.48	11.19	7.69E-09	-0.08	7.47E-09	1.1	8.22E-09	76.68	7.69E-09	1%	
10/16	1636	29880	200.78	10.25	7.28E-09	0.00	7.28E-09	1.1	8.01E-09	79.70	7.70E-09	0%	
10/17	835	57540	216.77	8.44	7.33E-09	0.06	7.57E-09	1.1	8.33E-09	85.52	7.75E-09	1%	
10/18	910	88500	241.35	6.00	6.49E-09	0.00	6.49E-09	1.1	7.14E-09	93.35	7.68E-09	1%	
10/18	911	60	241.37	31.50	6.49E-09	0.00	6.49E-09	1.1	7.14E-09	93.35	7.68E-09	0%	Refill
10/19	940	88140	265.85	28.50	7.17E-09	0.19	7.63E-09	1.1	8.39E-09	102.99	7.75E-09	1%	
10/19	1642	25320	272.88	27.44	8.90E-09	-0.13	7.81E-09	1.1	8.59E-09	106.39	7.77E-09	0%	
10/20	1704	87720	297.25	24.81	6.43E-09	-0.25	5.82E-09	1.1	6.40E-09	114.84	7.66E-09	1%	
10/21	1708	86640	321.32	22.75	5.16E-09	0.13	5.48E-09	1.1	6.03E-09	121.46	7.54E-09	2%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-10
Geometric factor-G=0.04534
Depth factor=165.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/22	1729	87660	345.67	20.69	5.15E-09	0.00	5.15E-09	1.1	5.66E-09	128.08	7.41E-09	2%	
10/23	1711	85320	369.37	18.44	5.84E-09	–	5.84E-09	1.1	6.42E-09	135.30	7.34E-09	1%	
10/24	1613	82920	392.40	16.25	5.91E-09	–	5.91E-09	1.1	6.50E-09	142.34	7.29E-09	1%	
10/25	1626	90780	417.62	14.00	5.61E-09	-0.31	4.83E-09	1.1	5.32E-09	149.57	7.17E-09	2%	+1 Hr Daylight
10/26	1620	86040	441.52	11.69	6.15E-09	-0.44	4.97E-09	1.1	5.47E-09	156.99	7.08E-09	1%	Savings Time
10/27	813	57180	457.40	10.06	6.59E-09	0.06	6.83E-09	1.1	7.52E-09	162.22	7.10E-09	0%	

END OF TEST TSB-10

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-11
Geometric factor-G=0.04030
Depth factor=234.75"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/08	0	0	0.00	33.75	-	-	-	-	-	0.00	-	-	START
10/08	1216	16860	4.68	32.87	7.85E-09	0.00	7.85E-09	1.1	8.63E-09	2.83	8.63E-09	-	
10/08	1545	12540	8.17	32.56	3.72E-09	0.00	3.72E-09	1.1	4.10E-09	3.82	6.70E-09	25%	
10/09	816	59460	24.68	30.87	4.30E-09	-0.32	3.48E-09	1.1	3.83E-09	9.25	4.78E-09	33%	
10/09	1007	6660	26.53	30.68	4.33E-09	-0.12	1.59E-09	1.1	1.75E-09	9.86	4.57E-09	5%	
10/09	1542	20100	32.12	30.38	2.27E-09	0.00	2.27E-09	1.1	2.49E-09	10.83	4.21E-09	8%	
10/10	832	60600	48.95	28.94	3.62E-09	-0.12	3.32E-09	1.1	3.65E-09	15.45	4.02E-09	5%	
10/10	1225	13980	52.83	28.69	2.73E-09	-0.19	6.56E-10	1.1	7.22E-10	16.25	3.77E-09	6%	
10/10	1625	14400	56.83	28.50	2.02E-09	0.06	2.66E-09	1.1	2.92E-09	16.87	3.71E-09	2%	
10/11	826	57660	72.85	26.94	4.15E-09	-0.12	3.83E-09	1.1	4.22E-09	21.88	3.82E-09	3%	
10/11	1155	12540	76.33	26.69	3.07E-09	-0.19	7.37E-10	1.1	8.11E-10	22.68	3.69E-09	4%	
10/11	1626	16260	80.85	26.56	1.23E-09	0.06	1.80E-09	1.1	1.98E-09	23.10	3.59E-09	3%	
10/12	817	57060	96.70	25.38	3.20E-09	-0.06	3.03E-09	1.1	3.34E-09	26.69	3.55E-09	1%	
10/12	1216	14340	100.68	25.00	4.11E-09	-0.19	2.05E-09	1.1	2.26E-09	28.11	3.50E-09	1%	
10/12	1554	13080	104.32	25.00	0.00E+00	0.12	1.42E-09	1.1	1.57E-09	28.11	3.43E-09	2%	
10/13	806	58440	120.55	23.50	3.99E-09	-0.12	3.67E-09	1.1	4.04E-09	32.93	3.51E-09	2%	
10/14	833	87900	144.97	22.25	2.22E-09	-0.25	1.78E-09	1.1	1.96E-09	36.94	3.25E-09	8%	
10/14	1630	28620	152.92	22.56	-1.7E-09	0.38	3.84E-10	1.1	4.22E-10	35.95	3.10E-09	5%	
10/15	839	58140	169.07	21.00	4.22E-09	-0.50	2.66E-09	1.1	3.15E-09	40.96	3.11E-09	0%	
10/15	1408	19740	174.55	20.94	4.79E-10	0.12	1.44E-09	1.1	1.58E-09	41.15	3.06E-09	2%	
10/16	817	65340	192.70	19.50	3.48E-09	-0.12	3.19E-09	1.1	3.51E-09	45.76	3.10E-09	1%	
10/16	1635	29880	201.00	19.00	2.65E-09	-0.07	2.28E-09	1.1	2.51E-09	47.38	3.08E-09	1%	
10/17	835	57600	217.00	17.86	3.09E-09	0.00	3.09E-09	1.1	3.40E-09	50.98	3.10E-09	1%	
10/18	912	88620	241.62	16.38	2.71E-09	-0.06	2.60E-09	1.1	2.86E-09	55.80	3.08E-09	1%	
10/19	940	88080	266.08	14.88	2.74E-09	0.00	2.74E-09	1.1	3.02E-09	60.62	3.07E-09	0%	
10/19	1641	25260	273.10	14.50	2.43E-09	-0.06	2.05E-09	1.1	2.25E-09	61.84	3.05E-09	1%	
10/20	1706	87900	297.52	13.19	2.42E-09	-0.25	1.95E-09	1.1	2.15E-09	66.05	2.98E-09	2%	
10/21	1709	86580	321.57	12.25	1.77E-09	-0.06	1.65E-09	1.1	1.82E-09	69.07	2.89E-09	3%	
10/22	1730	87660	345.92	11.25	1.87E-09	0.00	1.87E-09	1.1	2.05E-09	72.28	2.83E-09	2%	
10/23	1715	85500	369.67	10.25	1.92E-09	-	1.92E-09	1.1	2.11E-09	75.49	2.79E-09	2%	
10/24	1615	82800	392.67	9.25	1.99E-09	-	1.99E-09	1.1	2.19E-09	78.70	2.75E-09	1%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-11
Geometric factor-G=0.04030
Depth factor=234.75"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/25	1630	90900	417.92	6.25	1.62E-09	-0.31	1.26E-09	1.1	1.38E-09	61.92	2.67E-09	3%	+1 Hr Daylight
10/26	1621	85660	441.77	7.00	2.42E-09	-0.50	1.45E-09	1.1	1.60E-09	65.93	2.61E-09	2%	Savings Time
10/27	613	57120	457.63	6.25	2.19E-09	-0.25	1.46E-09	1.1	1.61E-09	68.34	2.57E-09	1%	

END OF TEST TSB-11

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-12
Geometric factor-G=0.04534
Depth factor=266.0"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/06	1057	0	0.00	31.00	-	-	-	-	-	0.00	-	-	START
10/06	1230	5580	1.55	28.36	7.20E-08	0.00	7.20E-08	1.1	7.92E-08	6.42	7.92E-08	-	
10/06	1716	17160	6.32	28.36	1.80E-10	0.00	1.80E-10	1.1	1.97E-10	6.48	1.96E-08	121%	
10/09	819	54180	21.37	27.36	2.79E-09	-0.32	1.86E-09	1.1	2.07E-09	11.63	7.24E-09	92%	
10/09	1212	13980	25.25	27.06	3.54E-09	-0.12	2.21E-09	1.1	2.43E-09	12.66	6.50E-09	11%	
10/09	1614	14520	29.28	27.06	3.54E-09	0.00	3.54E-09	1.1	3.89E-09	12.66	6.15E-09	6%	Repeated value
10/10	856	60120	45.98	26.12	2.42E-09	-0.12	2.11E-09	1.1	2.32E-09	15.66	4.76E-09	25%	
10/11	850	86040	69.88	24.94	2.13E-09	-0.25	1.68E-09	1.1	1.85E-09	19.47	3.76E-09	23%	
10/11	1130	9600	72.55	24.81	2.11E-09	-0.12	1.62E-10	1.1	1.79E-10	19.69	3.63E-09	4%	
10/12	745	72900	92.80	24.13	1.46E-09	0.00	1.46E-09	1.1	1.60E-09	22.07	3.19E-09	13%	
10/12	1149	14640	96.87	23.86	2.67E-09	-0.12	1.39E-09	1.1	1.53E-09	22.87	3.12E-09	2%	
10/13	740	71460	116.72	23.31	1.25E-09	-0.12	9.86E-10	1.1	1.08E-09	24.70	2.77E-09	12%	
10/14	906	91560	142.15	22.25	1.82E-09	-0.25	1.39E-09	1.1	1.53E-09	26.11	2.55E-09	8%	
10/15	818	83520	165.35	21.75	9.42E-10	-0.12	7.16E-10	1.1	7.88E-10	29.72	2.30E-09	10%	
10/16	856	88680	189.98	21.56	3.36E-10	0.00	3.36E-10	1.1	3.71E-10	30.33	2.05E-09	11%	
10/16	1652	28560	197.92	20.25	7.25E-09	-0.07	6.86E-09	1.1	7.55E-09	34.53	2.27E-09	10%	
10/17	812	55200	213.25	19.25	2.67E-09	0.00	2.67E-09	1.1	3.16E-09	37.75	2.34E-09	3%	
10/18	844	88320	237.78	17.94	2.36E-09	-0.06	2.25E-09	1.1	2.48E-09	41.95	2.35E-09	1%	
10/19	1008	91440	263.18	16.63	2.29E-09	0.00	2.29E-09	1.1	2.52E-09	46.16	2.37E-09	1%	
10/19	1657	24540	270.00	16.36	1.84E-09	-0.06	1.24E-09	1.1	1.37E-09	46.97	2.34E-09	1%	
10/20	1630	84780	293.55	15.31	2.03E-09	-0.25	1.56E-09	1.1	1.71E-09	50.40	2.29E-09	2%	
10/21	1626	86160	317.48	14.50	1.52E-09	-0.06	1.40E-09	1.1	1.55E-09	53.01	2.24E-09	2%	
10/22	1656	88200	341.98	13.69	1.49E-09	0.00	1.49E-09	1.1	1.64E-09	55.61	2.19E-09	2%	
10/23	1630	84840	365.55	12.63	2.03E-09	-	2.03E-09	1.1	2.23E-09	59.01	2.19E-09	0%	Replacement
10/24	1530	82800	388.55	11.50	2.23E-09	-	2.23E-09	1.1	2.45E-09	62.64	2.21E-09	1%	TEG Stabilizg
10/25	1551	91260	413.90	10.63	1.56E-09	-0.31	1.00E-09	1.1	1.10E-09	65.44	2.14E-09	3%	+1 Hr Daylight
10/26	824	59580	430.45	9.50	3.11E-09	-0.35	2.15E-09	1.1	2.36E-09	69.07	2.15E-09	0%	Savings Time

END OF TEST TSB-12

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-13
Geometric factor-G=0.04030
Depth factor=356.8"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/08	1018	0	0.00	34.12	-	-	-	-	-	0.00	-	-	START
10/08	1233	8100	2.25	32.69	1.82E-08	0.00	1.82E-08	1.1	2.01E-08	4.59	2.01E-08	-	
10/08	1717	17040	6.98	31.75	5.71E-09	0.00	5.71E-09	1.1	6.29E-09	7.61	1.07E-08	61%	
10/09	820	54180	22.03	29.13	5.03E-09	-0.32	4.42E-09	1.1	4.86E-09	16.03	6.72E-09	46%	
10/09	1213	13980	25.92	28.50	4.71E-09	-0.12	3.81E-09	1.1	4.19E-09	18.05	6.34E-09	6%	
10/09	1615	14520	29.95	28.19	2.23E-09	0.00	2.23E-09	1.1	2.46E-09	19.05	5.82E-09	9%	
10/10	857	60120	46.65	26.06	3.72E-09	-0.12	3.51E-09	1.1	3.86E-09	25.89	5.12E-09	13%	
10/10	1244	13620	50.43	25.56	3.87E-09	-0.19	2.40E-09	1.1	2.64E-09	27.50	4.93E-09	4%	
10/11	851	72420	70.55	22.94	3.83E-09	-0.06	3.74E-09	1.1	4.11E-09	35.92	4.70E-09	5%	
10/11	1130	9540	73.20	22.56	4.23E-09	-0.19	2.11E-09	1.1	2.33E-09	37.14	4.61E-09	2%	
10/11	1550	15600	77.53	22.25	2.11E-09	0.06	2.52E-09	1.1	2.77E-09	38.13	4.51E-09	2%	
10/12	746	57360	93.47	20.50	3.25E-09	-0.06	3.14E-09	1.1	3.45E-09	43.75	4.33E-09	4%	
10/12	1150	14640	97.53	19.94	4.09E-09	-0.19	2.70E-09	1.1	2.97E-09	45.56	4.27E-09	1%	
10/12	1534	13440	101.27	19.81	1.03E-09	0.12	1.99E-09	1.1	2.19E-09	45.97	4.19E-09	2%	
10/13	741	58020	117.38	18.06	3.24E-09	-0.12	3.01E-09	1.1	3.31E-09	51.59	4.07E-09	3%	
10/13	1631	31800	126.22	17.44	2.10E-09	-0.31	1.05E-09	1.1	1.15E-09	53.58	3.87E-09	5%	
10/14	907	59760	142.82	15.63	3.27E-09	0.06	3.38E-09	1.1	3.72E-09	59.40	3.85E-09	0%	
10/14	1552	24300	149.57	15.81	-8.0E-10	0.38	8.91E-10	1.1	9.80E-10	58.82	3.72E-09	3%	
10/15	819	59220	166.02	13.81	3.86E-09	-0.50	2.75E-09	1.1	3.02E-09	65.24	3.65E-09	2%	
10/15	1432	22380	172.23	13.50	1.51E-09	0.12	2.09E-09	1.1	2.30E-09	66.24	3.60E-09	1%	
10/16	857	66300	190.65	11.56	3.19E-09	-0.12	2.99E-09	1.1	3.29E-09	72.47	3.57E-09	1%	
10/16	1653	28560	198.58	10.88	2.61E-09	-0.07	2.34E-09	1.1	2.57E-09	74.66	3.53E-09	1%	
10/17	813	55200	213.92	9.38	2.98E-09	0.00	2.98E-09	1.1	3.28E-09	79.46	3.52E-09	1%	
10/18	845	88320	238.45	7.25	2.66E-09	-0.06	2.59E-09	1.1	2.85E-09	86.32	3.45E-09	2%	
10/19	1009	91440	263.85	5.06	2.66E-09	0.00	2.66E-09	1.1	2.93E-09	93.35	3.40E-09	1%	
10/19	1658	24540	270.67	4.56	2.27E-09	-0.06	2.00E-09	1.1	2.20E-09	94.96	3.37E-09	1%	
10/20	1630	84720	294.20	2.75	2.39E-09	-0.25	2.06E-09	1.1	2.26E-09	100.77	3.28E-09	3%	
10/20	1730	3600	295.20	35.19	2.39E-09	0.00	2.06E-09	1.1	2.27E-09	101.02	3.27E-09	0%	Refill
10/21	1630	82800	318.20	32.86	2.88E-09	-0.06	2.80E-09	1.1	3.08E-09	108.44	3.26E-09	0%	
10/22	1656	87960	342.63	30.81	2.44E-09	0.00	2.44E-09	1.1	2.68E-09	115.09	3.22E-09	1%	
10/23	1633	85020	366.25	28.69	2.60E-09	-	2.60E-09	1.1	2.86E-09	121.90	3.20E-09	1%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE DATA

TSB-13
Geometric factor-G=0.04030
Depth factor=356.8"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (lwa)	RPD (K1wa)	Comments
10/24	1530	82620	389.20	26.83	2.81E-09	-	2.61E-09	1.1	2.87E-09	128.52	3.18E-09	1%	
10/25	1552	91320	414.57	24.83	2.31E-09	-0.37	1.88E-09	1.1	2.07E-09	134.94	3.11E-09	2%	+1 Hr Daylight
10/28	825	59580	431.12	23.00	2.90E-09	-0.89	1.67E-09	1.1	1.84E-09	140.18	3.06E-09	2%	Savings Time

END OF TEST TSB-13

ATTACHMENT 2B

TSB
SPREADSHEET CALCULATION SUMMARY

STAGE 2 (K2')

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-1 STAGE TWO
Geometric factor - G = 0.006576"
Depth factor = 239.12"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/26	1500	0	0.00	32.06	-	-	-	-	-	0	-	-	START
10/27	756	60960	16.93	22.63	9.70E-09	-0.25	9.44E-09	1.1	1.04E-08	30.34	1.04E-08	-	
10/27	1356	21600	22.93	21.25	4.09E-09	-0.13	3.70E-09	1.1	4.07E-09	34.76	8.73E-09	17%	
10/27	1616	8400	25.27	20.81	3.36E-09	0.13	4.36E-09	1.1	4.79E-09	36.20	8.37E-09	4%	
10/28	751	56100	40.85	17.31	4.04E-09	0.06	4.11E-09	1.1	4.52E-09	47.46	6.90E-09	19%	
10/28	1320	19740	46.33	16.13	3.90E-09	-0.03	3.80E-09	1.1	4.18E-09	51.26	6.56E-09	5%	
10/28	1712	13920	50.20	15.56	2.88E-09	-0.12	2.12E-09	1.1	2.33E-09	53.09	6.25E-09	5%	
10/29	743	52260	64.72	12.69	3.82E-09	-0.13	3.46E-09	1.1	3.80E-09	62.32	5.70E-09	9%	
10/29	1140	14220	68.67	11.94	3.50E-09	0.00	3.50E-09	1.1	3.85E-09	64.74	5.59E-09	2%	
10/29	1603	15780	73.05	11.25	2.91E-09	0.13	3.46E-09	1.1	3.81E-09	66.96	5.49E-09	2%	
10/29	1608	300	73.13	34.38	2.91E-09	0.00	3.46E-09	1.1	3.81E-09	66.96	5.49E-09	0%	Refill
10/30	812	57840	89.20	30.13	4.52E-09	0.00	4.52E-09	1.1	4.97E-09	80.63	5.39E-09	2%	
10/30	1200	13680	93.00	29.19	4.27E-09	-0.19	3.41E-09	1.1	3.75E-09	83.86	5.33E-09	1%	
10/30	1600	14400	97.00	28.38	3.51E-09	0.00	3.51E-09	1.1	3.86E-09	86.27	5.27E-09	1%	
10/31	731	55860	112.52	25.25	3.52E-09	-0.06	3.45E-09	1.1	3.80E-09	96.34	5.06E-09	4%	
10/31	1140	14940	116.67	24.38	3.69E-09	-0.13	3.13E-09	1.1	3.45E-09	99.14	5.01E-09	1%	
10/31	1513	12780	120.22	23.75	3.13E-09	0.00	3.13E-09	1.1	3.44E-09	101.16	4.96E-09	1%	
11/01	933	66000	138.55	21.56	2.12E-09	-0.19	1.93E-09	1.1	2.13E-09	108.21	4.58E-09	8%	
11/01	1511	20280	144.18	19.75	5.74E-09	0.07	5.96E-09	1.1	6.56E-09	114.03	4.66E-09	2%	
11/02	806	60900	161.10	17.38	2.52E-09	0.25	2.79E-09	1.1	3.07E-09	121.66	4.49E-09	4%	
11/02	1324	19080	166.40	16.38	3.42E-09	-0.07	3.18E-09	1.1	3.50E-09	124.88	4.46E-09	1%	
11/02	1538	8040	168.63	16.25	1.06E-09	0.13	2.12E-09	1.1	2.33E-09	125.30	4.43E-09	1%	
11/03	805	59220	185.08	13.56	2.99E-09	0.12	3.12E-09	1.1	3.43E-09	133.95	4.35E-09	2%	
11/03	1048	9780	187.80	13.00	3.79E-09	0.00	3.79E-09	1.1	4.17E-09	135.75	4.34E-09	0%	
11/03	1510	15720	192.17	12.56	1.86E-09	0.25	2.91E-09	1.1	3.20E-09	137.17	4.32E-09	1%	
11/04	812	61320	209.20	9.81	2.99E-09	0.00	2.99E-09	1.1	3.29E-09	146.02	4.23E-09	2%	
11/04	1609	28620	217.15	8.69	2.63E-09	0.07	2.80E-09	1.1	3.08E-09	149.62	4.19E-09	1%	
11/05	759	57000	232.98	6.25	2.90E-09	-0.06	2.83E-09	1.1	3.11E-09	157.47	4.12E-09	2%	
11/05	801	120	233.02	35.75	2.90E-09	0.00	2.83E-09	1.1	3.11E-09	157.47	4.12E-09	0%	Refill
11/05	1626	30300	241.43	33.63	4.27E-09	0.06	4.39E-09	1.1	4.83E-09	164.29	4.14E-09	1%	
11/06	805	56340	257.08	30.38	5.85E-09	0.06	5.92E-09	1.1	6.51E-09	174.75	4.13E-09	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-1 STAGE TWO
Geometric factor - G = 0.006576"
Depth factor = 239.12"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/06	1646	31380	265.80	28.69	3.35E-09	-0.06	3.23E-09	1.1	3.55E-09	180.19	4.11E-09	0%	
11/07	912	59040	282.20	25.63	3.25E-09	-0.06	3.19E-09	1.1	3.51E-09	190.03	4.07E-09	1%	
11/07	1600	24480	289.00	24.31	3.41E-09	-0.07	3.23E-09	1.1	3.55E-09	194.28	4.06E-09	0%	
11/08	635	59700	305.58	21.56	2.94E-09	0.07	3.01E-09	1.1	3.31E-09	203.13	4.02E-09	1%	
11/08	1605	27000	313.08	20.00	3.71E-09	-0.57	2.35E-09	1.1	2.59E-09	208.15	3.99E-09	1%	
11/09	722	55020	328.37	17.75	2.65E-09	-0.07	2.56E-09	1.1	2.82E-09	215.39	3.93E-09	1%	
11/09	1625	32580	337.42	16.38	2.74E-09	-0.13	2.48E-09	1.1	2.73E-09	219.79	3.90E-09	1%	
11/10	730	54300	352.50	14.19	2.65E-09	0.00	2.65E-09	1.1	2.91E-09	226.84	3.86E-09	1%	
11/10	1624	32040	361.40	12.75	2.97E-09	-0.19	2.58E-09	1.1	2.84E-09	231.47	3.83E-09	1%	END TEST

END OF TEST TSB-1 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-2 STAGE TWO
Geometric factor - G = 0.006459"
Depth factor = 358.75"
TC values from Replacement TEG-3

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	comments
10/26	1430	0	0.00	33.13	-	-	-	1.1	-	0	-	-	START
10/27	759	62940	17.48	32.38	-	-	-	1.1	-	106.80	-	-	Dry refill
10/27	1359	21600	23.48	17.94	2.86E-08	-0.13	2.83E-08	1.1	3.11E-08	153.06	7.96E-09	200%	
10/27	1616	8220	25.77	13.56	2.33E-08	0.19	2.44E-08	1.1	2.68E-08	167.15	9.63E-09	19%	
10/27	1623	420	25.88	32.63	2.33E-08	0.00	2.44E-08	1.1	2.68E-08	167.15	9.70E-09	1%	Refill
10/28	750	55620	41.33	2.31	2.38E-08	-0.19	2.36E-08	1.1	2.60E-08	264.71	1.58E-08	48%	
10/28	752	120	41.37	31.06	2.38E-08	0.00	2.36E-08	1.1	2.60E-08	264.71	1.58E-08	0%	Refill
10/28	1321	19740	46.85	19.50	2.50E-08	-0.13	2.47E-08	1.1	2.72E-08	301.91	1.71E-08	8%	
10/28	1713	13920	50.72	12.63	2.16E-08	0.32	2.26E-08	1.1	2.49E-08	324.01	1.77E-08	3%	
10/29	830	55020	66.00	35.50	2.16E-08	0.00	2.16E-08	1.1	2.38E-08	364.65	1.91E-08	8%	Dry refill
10/29	1141	11460	69.18	28.00	2.75E-08	-0.06	2.73E-08	1.1	3.00E-08	388.78	1.96E-08	3%	
10/29	1603	15720	73.55	19.13	2.42E-08	0.12	2.45E-08	1.1	2.70E-08	417.32	2.01E-08	2%	
10/29	1605	120	73.58	35.38	2.42E-08	0.00	2.45E-08	1.1	2.70E-08	417.32	2.01E-08	0%	Refill
10/30	815	58200	89.75	4.75	2.28E-08	-0.06	2.28E-08	1.1	2.50E-08	515.88	2.10E-08	4%	
10/30	817	120	89.78	35.50	2.28E-08	0.00	2.28E-08	1.1	2.51E-08	515.88	2.10E-08	0%	Refill
10/30	1202	13500	93.53	27.13	2.61E-08	-0.13	2.57E-08	1.1	2.82E-08	542.81	2.13E-08	1%	
10/30	1600	14280	97.50	19.13	2.41E-08	-0.06	2.39E-08	1.1	2.63E-08	568.55	2.15E-08	1%	
10/30	1605	300	97.58	35.50	2.41E-08	0.00	2.39E-08	1.1	2.63E-08	568.55	2.15E-08	0%	Refill
10/31	731	55560	113.02	6.50	2.26E-08	-0.12	2.25E-08	1.1	2.47E-08	661.86	2.19E-08	2%	
10/31	734	180	113.07	35.38	2.26E-08	0.00	2.25E-08	1.1	2.48E-08	661.86	2.19E-08	0%	Refill
10/31	1148	15240	117.30	25.94	2.61E-08	0.00	2.61E-08	1.1	2.87E-08	692.23	2.22E-08	1%	
10/31	1514	12360	120.73	19.38	2.28E-08	0.00	2.28E-08	1.1	2.51E-08	713.34	2.22E-08	0%	
10/31	1518	240	120.80	35.00	2.28E-08	0.00	2.28E-08	1.1	2.51E-08	713.34	2.22E-08	0%	Refill
11/01	931	65580	139.02	1.75	2.21E-08	-0.19	2.19E-08	1.1	2.41E-08	820.33	2.25E-08	1%	
11/01	937	360	139.12	33.63	2.21E-08	-0.19	2.19E-08	1.1	2.41E-08	820.33	2.25E-08	0%	Refill
11/01	1510	19980	144.67	21.81	2.51E-08	0.00	2.51E-08	1.1	2.76E-08	858.36	2.27E-08	1%	
11/02	811	61260	161.68	34.88	2.51E-08	0.00	2.51E-08	1.1	2.76E-08	928.54	2.01E-08	12%	Dry refill
11/02	1325	18840	166.92	23.50	2.55E-08	-0.13	2.53E-08	1.1	2.78E-08	965.15	2.33E-08	15%	
11/02	1540	8100	169.17	19.31	2.23E-08	0.05	2.26E-08	1.1	2.49E-08	978.64	2.34E-08	0%	
11/02	1636	3360	170.10	17.50	2.34E-08	0.13	2.51E-08	1.1	2.76E-08	984.46	2.34E-08	0%	
11/02	1640	240	170.17	35.19	2.34E-08	0.00	2.51E-08	1.1	2.76E-08	984.46	2.34E-08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-2 STAGE TWO
Geometric factor - G = 0.006459"
Depth factor = 358.75"
TC values from Replacement TEG-3

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	Kt	TC	KtC	visc. factor	KtCT	cumulative volume (cc)	K (twa)	RPD (Kt-wa)	comments
11/03	806	55560	185.80	5.88	2.28E-08	0.00	2.28E-08	1.1	2.51E-08	1078.77	2.35E-08	1%	
11/03	1049	9780	188.32	1.56	2.00E-08	0.00	2.00E-08	1.1	2.20E-08	1092.87	2.35E-08	0%	
11/03	1200	4260	189.50	35.50	2.00E-08	0.00	2.00E-08	1.1	2.20E-08	1097.89	1.90E-08	21%	Dry refill
11/03	1511	11460	192.68	28.50	2.56E-08	0.18	2.63E-08	1.1	2.89E-08	1120.21	2.38E-08	22%	
11/03	1601	3000	193.52	34.69	2.56E-08	0.00	2.63E-08	1.1	2.89E-08	1120.21	1.91E-08	21%	Refill
11/04	813	58320	209.72	4.06	2.28E-08	-0.12	2.27E-08	1.1	2.50E-08	1218.77	2.37E-08	22%	
11/04	815	120	209.75	33.88	2.28E-08	0.00	2.27E-08	1.1	2.50E-08	1218.77	2.37E-08	0%	Refill
11/04	1611	28560	217.68	17.50	2.45E-08	0.06	2.46E-08	1.1	2.70E-08	1271.47	2.38E-08	1%	
11/04	1614	180	217.73	35.75	2.45E-08	0.00	2.46E-08	1.1	2.71E-08	1271.47	2.38E-08	0%	Refill
11/05	804	57000	233.57	5.56	2.29E-08	0.00	2.29E-08	1.1	2.52E-08	1368.81	2.39E-08	0%	
11/05	806	120	233.60	35.56	2.29E-08	0.00	2.29E-08	1.1	2.52E-08	1368.81	2.39E-08	0%	Refill
11/05	1627	30060	241.95	18.81	2.37E-08	0.18	2.40E-08	1.1	2.63E-08	1422.50	2.40E-08	0%	
11/05	1629	120	241.98	35.38	2.37E-08	0.00	2.40E-08	1.1	2.64E-08	1422.50	2.40E-08	0%	Refill
11/06	806	58220	257.60	5.19	2.33E-08	-0.06	2.32E-08	1.1	2.55E-08	1519.64	2.41E-08	0%	
11/06	808	120	257.63	35.25	2.33E-08	0.00	2.32E-08	1.1	2.55E-08	1519.64	2.41E-08	0%	Refill
11/06	1649	31260	266.32	17.25	2.45E-08	0.16	2.48E-08	1.1	2.72E-08	1577.56	2.42E-08	0%	
11/06	1650	60	266.33	35.50	2.45E-08	0.00	2.48E-08	1.1	2.73E-08	1577.56	2.42E-08	0%	Refill
11/07	913	58980	282.72	3.56	2.35E-08	-0.06	2.35E-08	1.1	2.58E-08	1680.33	2.43E-08	0%	
11/07	915	120	282.75	35.25	2.35E-08	0.00	2.35E-08	1.1	2.59E-08	1680.33	2.43E-08	0%	Refill
11/07	1601	24360	289.52	20.94	2.49E-08	-0.06	2.48E-08	1.1	2.73E-08	1726.37	2.44E-08	0%	
11/07	1604	180	289.57	35.81	2.49E-08	0.00	2.48E-08	1.1	2.73E-08	1726.37	2.44E-08	0%	Refill
11/08	836	59520	306.10	4.75	2.26E-08	0.00	2.26E-08	1.1	2.49E-08	1826.31	2.44E-08	0%	
11/08	837	60	306.12	35.31	2.26E-08	0.00	2.26E-08	1.1	2.49E-08	1826.31	2.44E-08	0%	Refill
11/08	1607	27000	313.62	20.25	2.37E-08	-0.38	2.31E-08	1.1	2.54E-08	1874.77	2.44E-08	0%	
11/08	1608	60	313.63	35.81	2.37E-08	0.00	2.31E-08	1.1	2.54E-08	1874.77	2.44E-08	0%	Refill
11/09	723	54900	328.88	6.75	2.29E-08	0.44	2.32E-08	1.1	2.55E-08	1968.27	2.45E-08	0%	
11/09	724	60	328.90	34.81	2.29E-08	0.00	2.32E-08	1.1	2.55E-08	1968.27	2.45E-08	0%	Refill
11/09	1626	32520	337.93	16.38	2.42E-08	-0.12	2.40E-08	1.1	2.64E-08	2027.57	2.45E-08	0%	
11/09	1627	60	337.95	35.75	2.42E-08	0.00	2.40E-08	1.1	2.64E-08	2027.57	2.45E-08	0%	Refill
11/10	731	54240	353.02	6.25	2.35E-08	0.00	2.35E-08	1.1	2.59E-08	2122.49	2.46E-08	0%	
11/10	732	60	353.03	34.56	2.35E-08	0.00	2.35E-08	1.1	2.59E-08	2122.49	2.46E-08	0%	Refill
11/10	1620	31680	361.63	16.13	2.49E-08	-0.13	2.47E-08	1.1	2.71E-08	2181.79	2.46E-08	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-2 STAGE TWO
Geometric factor – G = 0.006459"
Depth factor = 358.75"
TC values from Replacement TEG-3

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	comments
11/10	1621	60	361.85	35.94	2.49E-08	0.00	2.47E-08	1.1	2.72E-08	2161.79	2.46E-08	0%	Refill
11/11	735	54480	376.98	5.81	2.39E-08	0.00	2.39E-08	1.1	2.63E-08	2278.74	2.47E-08	0%	
11/11	736	60	377.00	35.00	2.39E-08	0.00	2.39E-08	1.1	2.63E-08	2278.74	2.47E-08	0%	Refill
11/11	1344	22080	383.13	21.50	2.59E-08	0.08	2.60E-08	1.1	2.86E-08	2322.18	2.48E-08	0%	END TEST

END OF TEST TSB-2 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-3 STAGE TWO
Geometric factor – G = 0.006401"
Depth factor = 162.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	KI	TC	KIC	visc. factor	KICT	cumulative volume (cc)	K (twa)	RPD (KIwa)	Comments
10/26	1500	0	0.00	33.63	–	–	–	–	–	0.00	–	–	START
10/27	800	61200	17.00	29.31	5.92E-09	0.06	6.01E-09	1.1	6.61E-09	13.90	6.61E-09	–	
10/27	1400	57900	33.08	28.69	9.10E-10	-0.31	4.55E-10	1.1	5.00E-10	15.89	3.64E-09	58%	
10/28	755	64500	51.00	26.06	3.50E-09	0.06	3.58E-09	1.2	4.29E-09	24.36	3.67E-09	6%	
10/28	1325	19800	56.50	25.50	2.45E-09	-0.06	2.18E-09	1.1	2.40E-09	26.16	3.73E-09	4%	
10/28	1730	14700	60.58	25.06	2.60E-09	0.25	4.07E-09	1.1	4.48E-09	27.57	3.76E-09	1%	
10/29	747	51420	74.87	23.19	3.17E-09	0.00	3.17E-09	1.1	3.49E-09	33.59	3.72E-09	1%	
10/29	1142	14100	78.78	22.63	3.49E-09	0.00	3.49E-09	1.1	3.84E-09	35.39	3.73E-09	0%	
10/29	1612	16200	83.28	22.13	2.72E-09	0.06	3.04E-09	1.1	3.35E-09	37.00	3.71E-09	1%	
10/30	821	58140	99.43	19.86	3.43E-09	0.00	3.43E-09	1.2	4.12E-09	44.24	3.77E-09	2%	
10/30	1209	13680	103.23	19.31	3.73E-09	-0.19	2.48E-09	1.2	2.98E-09	46.06	3.74E-09	1%	
10/30	1610	14460	107.25	18.86	2.67E-09	0.00	2.67E-09	1.1	2.93E-09	47.46	3.71E-09	1%	
10/31	739	55740	122.73	16.86	3.24E-09	0.00	3.24E-09	1.1	3.56E-09	53.89	3.70E-09	1%	
10/31	1151	15120	126.93	16.25	3.79E-09	-0.12	3.07E-09	1.1	3.37E-09	55.92	3.68E-09	0%	
10/31	1541	13800	130.77	15.81	2.91E-09	0.00	2.91E-09	1.1	3.20E-09	57.34	3.67E-09	0%	
11/01	940	64740	148.75	13.86	2.74E-09	-0.13	2.55E-09	1.1	2.81E-09	63.55	3.57E-09	3%	
11/01	1515	20100	154.33	13.44	2.02E-09	0.00	2.02E-09	1.1	2.23E-09	64.96	3.52E-09	1%	
11/02	816	61260	171.35	11.50	2.95E-09	0.32	3.44E-09	1.1	3.78E-09	71.21	3.54E-09	1%	
11/02	1326	18720	176.55	10.94	2.60E-09	-0.07	2.45E-09	1.2	2.94E-09	73.01	3.53E-09	1%	
11/02	1545	8220	178.83	10.75	2.17E-09	0.13	3.66E-09	1.2	4.39E-09	73.62	3.54E-09	0%	
11/03	810	59100	195.25	8.69	3.30E-09	0.12	3.49E-09	1.2	4.19E-09	80.25	3.59E-09	2%	
11/03	1053	9780	197.97	8.31	3.70E-09	0.00	3.70E-09	1.2	4.44E-09	81.47	3.60E-09	0%	
11/03	1520	16020	202.42	8.06	1.49E-09	0.32	3.40E-09	1.2	4.08E-09	82.27	3.61E-09	0%	
11/04	820	61200	219.42	5.94	3.33E-09	0.18	3.61E-09	1.2	4.33E-09	89.10	3.67E-09	2%	
11/04	822	120	219.45	35.38	3.33E-09	0.00	3.61E-09	1.2	4.33E-09	89.10	3.67E-09	0%	Refill
11/04	1617	28500	227.37	33.56	5.28E-09	0.07	5.48E-09	1.2	6.58E-09	94.96	3.77E-09	3%	
11/05	806	57060	243.22	30.69	4.21E-09	0.00	4.21E-09	1.2	5.05E-09	104.19	3.85E-09	2%	
11/05	1632	30240	251.62	29.36	3.66E-09	0.12	4.00E-09	1.2	4.80E-09	108.41	3.89E-09	1%	
11/06	812	56400	267.28	26.81	3.89E-09	0.06	3.98E-09	1.2	4.78E-09	116.67	3.94E-09	1%	
11/06	1654	31320	275.98	25.44	3.76E-09	-0.06	3.61E-09	1.2	4.33E-09	121.08	3.95E-09	0%	
11/07	859	57900	292.07	23.13	3.48E-09	0.13	3.67E-09	1.25	4.59E-09	128.52	3.99E-09	1%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-3 STAGE TWO
Geometric factor - G = 0.006401"
Depth factor = 162.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/07	1609	25800	299.23	22.13	3.41E-09	-0.25	2.55E-09	1.2	3.07E-09	131.73	3.96E-09	1%	
11/08	640	59460	315.75	19.88	3.36E-09	0.16	3.63E-09	1.25	4.53E-09	136.97	3.99E-09	1%	
11/08	1610	27000	323.25	16.75	3.75E-09	-0.81	1.06E-09	1.2	1.27E-09	142.81	3.93E-09	2%	
11/09	726	55080	338.55	16.94	2.97E-09	0.13	3.18E-09	1.2	3.82E-09	146.43	3.93E-09	0%	
11/09	1629	32460	347.57	15.66	2.97E-09	-0.19	2.44E-09	1.2	2.93E-09	151.84	3.90E-09	1%	
11/10	737	54480	362.70	14.13	2.95E-09	0.06	3.05E-09	1.2	3.66E-09	157.47	3.89E-09	0%	
11/10	1629	31920	371.57	13.13	2.90E-09	-0.31	2.00E-09	1.1	2.20E-09	160.69	3.85E-09	1%	
11/11	740	54660	386.75	11.50	2.78E-09	-0.06	2.67E-09	1.1	2.94E-09	165.94	3.81E-09	1%	
11/11	1400	22800	393.08	10.81	2.84E-09	-0.06	2.59E-09	1.1	2.85E-09	168.16	3.80E-09	0%	END TEST

END OF TEST TSB-3 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-4 STAGE TWO
Geometric factor - G = 0.006514"
Depth factor = 239.25"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/26	1549	0	0.00	31.06	-	-	-	-	-	0.00	-	-	START
10/27	802	58380	16.22	28.88	4.42E-09	-0.25	4.15E-09	1.1	4.57E-09	13.45	4.57E-09	-	
10/27	1402	21600	22.22	25.25	4.71E-09	-0.13	4.33E-09	1.1	4.76E-09	18.69	4.62E-09	1%	
10/28	755	64380	40.10	20.63	4.53E-09	0.06	4.59E-09	1.1	5.05E-09	33.56	4.81E-09	4%	
10/28	1325	19800	45.60	19.06	5.06E-09	-0.04	4.93E-09	1.1	5.43E-09	36.61	4.88E-09	2%	
10/28	1728	14580	49.65	18.19	3.83E-09	-0.12	3.30E-09	1.1	3.63E-09	41.41	4.78E-09	2%	
10/29	748	51600	63.98	14.56	4.55E-09	-0.13	4.39E-09	1.1	4.83E-09	53.09	4.79E-09	0%	
10/29	1143	14100	67.90	13.56	4.63E-09	0.00	4.63E-09	1.1	5.10E-09	58.31	4.81E-09	0%	
10/29	1613	16200	72.40	12.50	4.29E-09	0.13	4.82E-09	1.1	5.30E-09	59.72	4.84E-09	1%	
10/30	820	58020	88.52	8.69	4.35E-09	0.00	4.35E-09	1.1	4.78E-09	71.98	4.83E-09	0%	
10/30	1206	13560	92.28	7.75	4.63E-09	-0.19	3.70E-09	1.1	4.07E-09	75.00	4.80E-09	1%	
10/30	1208	120	92.32	32.63	4.63E-09	0.00	3.70E-09	1.1	4.07E-09	75.00	4.80E-09	0%	Refill
10/30	1608	14400	96.32	31.13	6.36E-09	0.00	6.36E-09	1.1	6.99E-09	79.83	4.89E-09	2%	
10/31	738	55800	111.82	28.25	5.40E-09	-0.06	5.33E-09	1.1	5.87E-09	95.53	5.03E-09	3%	
10/31	1151	15180	116.03	24.88	5.64E-09	-0.13	5.10E-09	1.1	5.61E-09	99.94	5.05E-09	0%	
10/31	1540	13740	119.85	23.75	5.16E-09	0.00	5.16E-09	1.1	5.68E-09	103.57	5.07E-09	0%	
11/01	942	64920	137.88	18.81	4.83E-09	-0.19	4.65E-09	1.1	5.11E-09	119.47	5.07E-09	0%	
11/01	1516	20040	143.45	17.44	4.39E-09	0.07	4.62E-09	1.1	5.08E-09	123.88	5.07E-09	0%	
11/02	814	61080	160.42	13.50	4.19E-09	0.25	4.46E-09	1.1	4.90E-09	136.55	5.05E-09	0%	
11/02	1328	18840	165.65	12.13	4.77E-09	-0.07	4.53E-09	1.1	4.98E-09	140.96	5.05E-09	0%	
11/02	1546	8280	167.95	11.75	3.02E-09	0.13	4.06E-09	1.1	4.46E-09	142.18	5.04E-09	0%	
11/03	811	59100	184.37	7.75	4.50E-09	0.12	4.63E-09	1.1	5.10E-09	155.05	5.05E-09	0%	
11/03	1052	9660	187.05	7.06	4.79E-09	0.00	4.79E-09	1.1	5.27E-09	157.27	5.05E-09	0%	
11/03	1522	16200	191.55	6.19	3.61E-09	0.25	4.65E-09	1.1	5.12E-09	160.07	5.05E-09	0%	
11/04	825	61380	208.60	2.25	4.36E-09	0.00	4.36E-09	1.1	4.80E-09	172.75	5.03E-09	0%	
11/04	828	180	208.65	35.75	4.36E-09	0.00	4.36E-09	1.1	4.80E-09	172.75	5.03E-09	0%	Refill
11/04	1618	28200	216.48	32.75	6.44E-09	0.07	6.59E-09	1.1	7.25E-09	182.40	5.11E-09	2%	
11/05	809	57060	232.33	27.63	5.51E-09	0.00	5.51E-09	1.1	6.06E-09	198.88	5.18E-09	1%	
11/05	1633	30240	240.73	25.13	5.15E-09	0.06	5.27E-09	1.1	5.80E-09	206.92	5.20E-09	0%	
11/06	813	56400	256.40	20.50	5.18E-09	0.06	5.25E-09	1.1	5.78E-09	221.82	5.23E-09	1%	
11/06	1655	31320	265.10	18.06	4.99E-09	-0.06	4.86E-09	1.1	5.35E-09	229.67	5.24E-09	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-4 STAGE TWO
Geometric factor - G = 0.006514"
Depth factor = 239.25"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/07	900	57900	281.18	13.75	4.83E-09	-0.06	4.76E-09	1.1	5.24E-09	243.54	5.24E-09	0%	
11/07	1610	25800	288.35	11.86	4.76E-09	-0.07	4.58E-09	1.1	5.04E-09	249.55	5.23E-09	0%	
11/08	841	59460	304.87	7.81	4.55E-09	0.07	4.63E-09	1.1	5.09E-09	262.65	5.23E-09	0%	
11/08	842	60	304.88	36.00	4.55E-09	0.00	4.63E-09	1.1	5.09E-09	262.65	5.23E-09	0%	Refill
11/08	1611	26940	312.37	32.86	7.00E-09	-0.57	5.72E-09	1.1	6.29E-09	272.69	5.25E-09	0%	
11/09	729	55080	327.67	27.75	5.72E-09	-0.07	5.64E-09	1.1	6.20E-09	289.20	5.30E-09	1%	
11/09	1630	32460	336.68	24.81	5.64E-09	-0.13	5.39E-09	1.1	5.93E-09	298.65	5.31E-09	0%	
11/10	736	54460	351.82	20.36	5.14E-09	0.00	5.14E-09	1.1	5.65E-09	312.91	5.33E-09	0%	
11/10	1630	31920	360.68	17.86	5.02E-09	-0.19	4.83E-09	1.1	5.10E-09	320.95	5.32E-09	0%	
11/11	741	54660	375.87	14.00	4.60E-09	0.00	4.60E-09	1.1	5.06E-09	333.44	5.31E-09	0%	
11/11	1401	22800	382.20	12.36	4.66E-09	0.00	4.66E-09	1.1	5.12E-09	338.65	5.31E-09	0%	END TEST

END OF TEST TSB-4 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-5 STAGE TWO
Geometric factor - G = 0.006576"
Depth factor = 153.5"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	1140	0	0.00	33.86	-	-	-	1.1	-	0.00	-	-	START
10/27	1452	9900	2.75	32.31	1.42E-08	-0.31	4.48E-09	1.1	4.93E-09	5.05	4.93E-09	-	
10/27	1607	6120	4.45	32.21	1.47E-09	0.13	1.33E-09	1.1	1.46E-09	5.37	3.61E-09	31%	
10/28	810	57780	20.50	31.25	1.50E-09	0.06	6.27E-10	1.2	7.52E-10	8.46	1.37E-09	90%	
10/28	1345	20100	26.08	31.06	6.55E-10	-0.06	2.30E-10	1.1	2.53E-10	9.07	1.13E-09	19%	
10/28	1748	14580	30.13	31.00	3.72E-10	0.25	7.58E-10	1.1	8.34E-10	9.27	1.09E-09	4%	
10/29	751	50580	44.18	29.86	2.01E-09	0.00	7.92E-10	1.1	8.71E-10	12.67	1.02E-09	7%	
10/29	1158	14820	48.30	29.56	1.97E-09	0.00	7.75E-10	1.1	8.52E-10	13.90	1.01E-09	1%	
10/29	1638	16800	52.97	29.25	1.69E-09	0.06	7.92E-10	1.1	8.71E-10	14.90	9.95E-10	1%	
10/30	845	58020	69.08	27.88	2.17E-09	0.00	8.53E-10	1.2	1.02E-09	19.31	1.00E-09	1%	
10/30	1227	13320	72.78	27.50	2.63E-09	-0.19	5.17E-10	1.2	6.21E-10	20.53	9.83E-10	2%	
10/30	1638	15060	76.97	27.25	1.53E-09	0.00	6.04E-10	1.1	6.64E-10	21.33	9.65E-10	2%	
10/31	807	55740	92.45	25.75	2.50E-09	0.00	9.83E-10	1.1	1.08E-09	26.16	9.85E-10	2%	
10/31	1210	14580	96.50	25.38	2.37E-09	-0.12	6.29E-10	1.1	6.92E-10	27.35	9.72E-10	1%	
10/31	1552	13320	100.20	25.13	1.75E-09	0.00	6.90E-10	1.1	7.60E-10	28.15	9.65E-10	1%	
11/01	1018	66360	118.63	23.56	2.22E-09	-0.13	6.02E-10	1.1	6.62E-10	33.21	9.52E-10	1%	
11/01	1540	19320	124.00	23.25	1.51E-09	0.00	5.96E-10	1.1	6.56E-10	34.20	9.39E-10	1%	
11/02	853	61980	141.22	21.56	2.59E-09	0.32	1.21E-09	1.1	1.33E-09	39.64	9.87E-10	5%	
11/02	1343	17400	146.05	21.06	2.75E-09	-0.07	9.29E-10	1.2	1.12E-09	41.25	9.91E-10	0%	
11/02	1610	8820	148.50	20.75	3.37E-09	0.13	1.88E-09	1.2	2.26E-09	42.25	1.01E-09	2%	
11/03	815	57900	164.58	18.88	3.11E-09	0.12	1.30E-09	1.2	1.57E-09	48.26	1.07E-09	5%	
11/03	1107	10320	167.45	18.56	3.01E-09	0.00	1.18E-09	1.2	1.42E-09	49.29	1.07E-09	1%	
11/03	1530	15780	171.83	18.25	1.91E-09	0.32	1.53E-09	1.2	1.83E-09	50.29	1.09E-09	2%	
11/04	832	61320	188.87	16.06	3.50E-09	0.18	1.49E-09	1.2	1.79E-09	57.34	1.15E-09	6%	
11/04	1638	29160	196.97	15.31	2.54E-09	0.07	1.09E-09	1.2	1.31E-09	59.75	1.16E-09	1%	
11/05	836	57780	213.02	13.63	2.89E-09	0.00	1.14E-09	1.2	1.37E-09	65.16	1.18E-09	1%	
11/05	1356	19200	218.35	13.00	3.29E-09	0.00	1.29E-09	1.2	1.55E-09	67.18	1.19E-09	1%	
11/05	1700	11040	221.42	12.75	2.27E-09	0.12	1.33E-09	1.2	1.59E-09	67.99	1.19E-09	0%	
11/06	829	55740	236.90	11.00	3.17E-09	0.06	1.29E-09	1.2	1.55E-09	73.62	1.21E-09	2%	
11/06	1715	31560	245.67	10.06	3.03E-09	0.00	1.19E-09	1.2	1.43E-09	76.64	1.22E-09	1%	
11/07	833	55080	260.97	8.50	2.91E-09	0.13	1.24E-09	1.25	1.55E-09	81.66	1.24E-09	2%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-5 STAGE TWO
Geometric factor – G = 0.006576"
Depth factor = 153.5"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/07	1613	27600	268.63	7.69	3.03E-09	-0.25	8.25E-10	1.2	9.90E-10	84.27	1.23E-09	1%	
11/08	908	60900	285.55	5.88	3.10E-09	0.18	1.34E-09	1.25	1.68E-09	90.09	1.26E-09	2%	
11/08	909	60	285.57	35.50	3.10E-09	0.00	1.34E-09	1.25	1.68E-09	90.09	1.26E-09	0%	Refill
11/08	1615	25560	292.67	34.00	5.21E-09	-0.81	9.41E-10	1.2	1.13E-09	94.92	1.26E-09	0%	
11/09	753	56280	308.30	31.94	3.28E-09	0.13	1.37E-09	1.2	1.65E-09	101.54	1.26E-09	2%	
11/09	1634	31260	316.98	30.88	3.08E-09	-0.19	9.89E-10	1.2	1.19E-09	104.96	1.27E-09	0%	
11/10	740	54360	332.08	29.19	2.83E-09	0.08	1.15E-09	1.2	1.38E-09	110.39	1.28E-09	0%	
11/10	1632	31920	340.95	27.69	4.31E-09	-0.31	1.35E-09	1.2	1.62E-09	115.22	1.29E-09	1%	
11/11	805	55980	356.50	25.25	4.05E-09	-0.08	1.55E-09	1.2	1.86E-09	123.07	1.31E-09	2%	
11/11	1354	20940	362.32	23.75	6.72E-09	-0.08	2.54E-09	1.2	3.05E-09	127.90	1.34E-09	2%	END TEST

END OF TEST TSB-5 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-6 STAGE TWO
Geometric factor - G = 0.006190"
Depth factor=231.5"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	1210	0	0.00	32.63	-	-	-	1.1	-	0.00	-	-	START
10/27	1430	8400	2.33	29.25	2.41E-08	-0.13	2.32E-08	1.1	2.55E-08	10.66	2.55E-08	-	
10/27	1606	5760	3.93	27.75	1.57E-08	0.13	1.71E-08	1.1	1.88E-08	15.70	2.26E-08	11%	
10/28	809	57924	20.02	12.50	1.65E-08	0.06	1.65E-08	1.1	1.82E-08	64.77	1.91E-08	18%	
10/28	1346	20220	25.64	6.31	1.35E-08	-0.05	1.33E-08	1.1	1.46E-08	76.25	1.81E-08	5%	
10/28	1350	240	25.71	33.63	1.35E-08	0.00	1.33E-08	1.1	1.46E-08	76.25	1.81E-08	0%	Refill
10/28	1746	14160	29.64	29.75	1.64E-08	-0.12	1.59E-08	1.1	1.74E-08	90.73	1.80E-08	0%	
10/29	752	50760	43.74	17.38	1.50E-08	-0.13	1.49E-08	1.1	1.63E-08	130.54	1.75E-08	3%	
10/29	1200	14880	47.87	14.00	1.44E-08	0.00	1.44E-08	1.1	1.59E-08	141.41	1.73E-08	1%	
10/29	1640	16800	52.54	10.44	1.37E-08	0.13	1.42E-08	1.1	1.56E-08	152.87	1.72E-08	1%	
10/29	1642	120	52.57	34.25	1.37E-08	0.00	1.42E-08	1.1	1.56E-08	152.87	1.72E-08	0%	Refill
10/30	846	57840	68.64	20.00	1.50E-08	0.00	1.50E-08	1.1	1.65E-08	198.72	1.70E-08	1%	
10/30	1226	13200	72.31	17.25	1.31E-08	-0.19	1.22E-08	1.1	1.34E-08	207.57	1.68E-08	1%	
10/30	1639	15180	76.52	14.25	1.26E-08	0.00	1.26E-08	1.1	1.38E-08	217.22	1.67E-08	1%	
10/30	1644	300	76.61	34.63	1.26E-08	0.00	1.26E-08	1.1	1.39E-08	217.22	1.67E-08	0%	Refill
10/31	808	55440	92.01	21.50	1.43E-08	-0.06	1.43E-08	1.1	1.57E-08	259.47	1.65E-08	1%	
10/31	1211	14580	96.06	18.44	1.31E-08	-0.13	1.26E-08	1.1	1.38E-08	269.31	1.64E-08	1%	
10/31	1553	13320	99.76	15.75	1.28E-08	0.00	1.28E-08	1.1	1.41E-08	277.97	1.63E-08	1%	
10/31	1557	240	99.82	35.00	1.28E-08	0.00	1.28E-08	1.1	1.41E-08	277.97	1.63E-08	0%	Refill
11/01	1017	66000	118.16	20.31	1.35E-08	-0.19	1.33E-08	1.1	1.47E-08	325.24	1.60E-08	2%	
11/01	1541	19440	123.56	16.44	1.25E-08	0.07	1.28E-08	1.1	1.40E-08	337.69	1.60E-08	1%	
11/01	1545	240	216.50	34.56	1.25E-08	0.00	1.28E-08	1.1	1.41E-08	337.69	9.11E-09	55%	Refill
11/02	853	61680	233.63	21.81	1.25E-08	0.25	1.28E-08	1.1	1.40E-08	378.71	9.47E-09	4%	
11/02	1344	17460	238.48	18.63	1.14E-08	-0.07	1.11E-08	1.1	1.22E-08	388.95	9.53E-09	1%	
11/02	1612	8880	240.95	17.13	1.06E-08	0.13	1.16E-08	1.1	1.27E-08	393.77	9.56E-09	0%	
11/03	816	57840	257.02	7.13	1.12E-08	0.12	1.13E-08	1.1	1.24E-08	425.95	9.74E-09	2%	
11/03	1106	10200	259.85	5.44	1.10E-08	0.00	1.10E-08	1.1	1.21E-08	431.39	9.77E-09	0%	
11/03	1529	15780	264.23	3.13	9.76E-09	0.25	1.08E-08	1.1	1.19E-08	438.82	9.80E-09	0%	
11/03	1532	180	264.28	33.69	9.76E-09	0.00	1.08E-08	1.1	1.19E-08	438.82	9.80E-09	0%	Refill
11/04	833	61260	281.30	21.00	1.26E-08	0.00	1.26E-08	1.1	1.38E-08	479.65	1.00E-08	2%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-6 STAGE TWO
Geometric factor - G = 0.006190"
Depth factor=231.5"
TC values from TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/04	1639	29160	289.40	15.81	1.12E-08	0.07	1.14E-08	1.1	1.25E-08	496.35	1.01E-08	1%	
11/04	1642	180	289.45	34.25	1.12E-08	0.00	1.14E-08	1.1	1.25E-08	496.35	1.01E-08	0%	Refill
11/05	838	57360	305.38	22.94	1.19E-08	0.00	1.19E-08	1.1	1.31E-08	532.74	1.03E-08	2%	
11/05	1357	19140	310.70	19.50	1.12E-08	0.00	1.12E-08	1.1	1.23E-08	543.81	1.03E-08	0%	
11/05	1659	10920	313.73	17.63	1.08E-08	0.06	1.11E-08	1.1	1.22E-08	549.83	1.03E-08	0%	
11/06	830	55860	329.25	6.25	1.08E-08	0.06	1.09E-08	1.1	1.20E-08	580.01	1.04E-08	1%	
11/06	832	120	329.28	34.88	1.08E-08	0.00	1.09E-08	1.1	1.20E-08	580.01	1.04E-08	0%	Refill
11/06	1716	31440	338.02	28.25	1.26E-08	-0.06	1.25E-08	1.1	1.37E-08	601.34	1.05E-08	1%	
11/07	834	55080	353.32	18.19	1.13E-08	-0.06	1.12E-08	1.1	1.23E-08	633.71	1.06E-08	1%	
11/07	1614	27600	360.98	13.63	1.05E-08	-0.07	1.03E-08	1.1	1.14E-08	646.38	1.06E-08	0%	
11/08	911	61020	377.93	3.69	1.07E-08	0.07	1.07E-08	1.1	1.18E-08	660.37	1.06E-08	1%	
11/08	912	60	377.95	34.81	1.07E-08	0.00	1.07E-08	1.1	1.18E-08	660.37	1.06E-08	0%	Refill
11/08	1616	25440	385.02	29.63	1.21E-08	-0.57	1.08E-08	1.1	1.19E-08	697.04	1.07E-08	0%	
11/09	754	56280	400.65	19.13	1.15E-08	-0.07	1.14E-08	1.1	1.25E-08	730.82	1.07E-08	1%	
11/09	1635	31260	409.33	13.75	1.09E-08	-0.13	1.06E-08	1.1	1.17E-08	746.13	1.08E-08	0%	
11/09	1637	120	409.37	35.19	1.09E-08	0.00	1.06E-08	1.1	1.17E-08	746.13	1.08E-08	0%	Refill
11/10	741	54240	424.43	24.44	1.19E-08	0.00	1.19E-08	1.1	1.31E-08	782.72	1.08E-08	1%	
11/10	1633	31920	433.30	16.75	1.11E-08	-0.19	1.07E-08	1.1	1.18E-08	801.03	1.09E-08	0%	
11/11	803	55800	448.80	9.63	1.05E-08	0.00	1.05E-08	1.1	1.15E-08	830.37	1.09E-08	0%	
11/11	1355	21120	454.67	6.25	1.05E-08	0.00	1.05E-08	1.1	1.16E-08	841.25	1.09E-08	0%	END TEST

END OF TEST TSB-6 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-7 STAGE TWO
Geometric factor – G = 0.006634"
Depth factor = 161.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	1015	0	0.00	34.25	–	–	–	1.1	–	0.00	–	–	START
10/27	1421	14760	3.63	33.56	4.04E-09	-0.31	2.22E-09	1.1	2.44E-09	2.22	2.76E-09	–	
10/27	1605	6240	5.36	33.50	8.32E-10	0.13	2.83E-09	1.1	2.90E-09	2.41	2.80E-09	2%	
10/28	815	58200	21.53	32.81	1.03E-09	0.08	1.12E-09	1.2	1.34E-09	4.83	1.71E-09	49%	
10/28	1340	19500	26.95	32.56	1.11E-09	-0.06	8.46E-10	1.1	9.31E-10	5.44	1.55E-09	10%	
10/28	1751	57420	42.90	32.38	2.73E-10	0.25	6.52E-10	1.1	7.17E-10	6.02	1.24E-09	22%	
10/29	756	50700	56.98	31.75	1.08E-09	0.00	1.08E-09	1.1	1.19E-09	8.04	1.23E-09	1%	
10/29	1202	14760	61.08	31.63	7.10E-10	0.00	7.10E-10	1.1	7.81E-10	8.43	1.20E-09	2%	
10/29	1645	16980	65.80	31.44	9.78E-10	0.08	1.29E-09	1.1	1.42E-09	9.04	1.21E-09	1%	
10/30	849	57840	81.86	30.75	1.05E-09	0.00	1.05E-09	1.2	1.25E-09	11.26	1.22E-09	1%	
10/30	1230	13284	85.55	30.53	1.26E-09	-0.19	1.05E-09	1.2	1.26E-09	11.87	1.22E-09	0%	Repeated value
10/30	1632	14520	89.59	30.44	7.26E-10	0.00	7.26E-10	1.1	7.99E-10	12.26	1.20E-09	2%	
10/31	802	55800	105.09	29.75	1.09E-09	0.00	1.09E-09	1.1	1.20E-09	14.48	1.20E-09	0%	
10/31	1209	14820	109.20	29.50	1.49E-09	-0.12	7.74E-10	1.1	8.52E-10	15.28	1.19E-09	1%	
10/31	1545	12960	112.80	29.38	8.18E-10	0.00	8.18E-10	1.1	9.00E-10	15.87	1.18E-09	1%	
11/01	1009	66240	131.20	28.63	1.00E-09	-0.13	8.29E-10	1.1	9.12E-10	18.08	1.14E-09	3%	
11/01	1534	19500	136.62	28.44	8.65E-10	0.00	8.65E-10	1.1	9.52E-10	18.69	1.14E-09	1%	
11/02	850	52500	151.20	27.56	1.49E-09	0.32	2.04E-09	1.1	2.24E-09	21.53	1.24E-09	9%	
11/02	1341	17460	156.05	27.38	9.20E-10	-0.07	5.62E-10	1.2	6.75E-10	22.10	1.22E-09	1%	
11/02	1614	9180	158.60	27.25	1.27E-09	0.13	2.53E-09	1.2	3.04E-09	22.52	1.25E-09	2%	
11/03	818	57840	174.67	26.31	1.46E-09	0.12	1.64E-09	1.2	1.97E-09	25.55	1.32E-09	5%	
11/03	1105	10020	177.45	26.13	1.61E-09	0.00	1.61E-09	1.2	1.94E-09	26.13	1.33E-09	1%	
11/03	1525	15600	181.79	26.00	7.50E-10	0.32	2.60E-09	1.2	3.12E-09	26.55	1.37E-09	3%	
11/04	835	61800	198.95	24.94	1.55E-09	0.18	1.81E-09	1.2	2.17E-09	29.96	1.44E-09	5%	
11/04	1644	29340	207.10	24.50	1.36E-09	0.07	1.58E-09	1.2	1.89E-09	31.37	1.46E-09	1%	
11/05	841	57420	223.05	23.56	1.49E-09	0.00	1.49E-09	1.2	1.79E-09	34.40	1.48E-09	2%	
11/05	1354	18780	228.27	23.25	1.51E-09	0.00	1.51E-09	1.2	1.81E-09	35.39	1.49E-09	1%	
11/05	1655	10860	231.29	23.06	1.60E-09	0.12	2.61E-09	1.2	3.13E-09	36.00	1.51E-09	1%	
11/06	834	56340	246.94	22.19	1.42E-09	0.06	1.51E-09	1.2	1.82E-09	38.80	1.53E-09	1%	
11/06	1710	30960	255.54	21.63	1.66E-09	-0.06	1.49E-09	1.2	1.78E-09	40.61	1.54E-09	1%	
11/07	836	55560	270.97	20.69	1.56E-09	0.13	1.78E-09	1.25	2.22E-09	43.63	1.56E-09	3%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-7 STAGE TWO
Geometric factor – G = 0.006634"
Depth factor = 161.25"
TC values from TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/07	1617	27660	278.65	20.25	1.48E-09	-0.25	6.37E-10	1.2	7.64E-10	45.05	1.56E-09	1%	
11/08	902	60300	295.40	19.19	1.64E-09	0.16	1.92E-09	1.25	2.39E-09	48.46	1.60E-09	3%	
11/08	1619	26220	302.69	18.75	1.57E-09	-0.81	1.32E-09	1.2	1.58E-09	49.87	1.60E-09	0%	
11/09	747	55660	318.15	17.94	1.36E-09	0.13	1.58E-09	1.2	1.90E-09	52.48	1.62E-09	1%	
11/09	1639	31920	327.02	17.50	1.30E-09	-0.19	7.37E-10	1.2	8.84E-10	53.89	1.60E-09	1%	
11/10	744	54300	342.10	16.89	1.41E-09	0.06	1.51E-09	1.2	1.82E-09	56.50	1.61E-09	1%	
11/10	1635	31860	350.95	16.13	1.67E-09	-0.31	7.44E-10	1.2	8.92E-10	58.30	1.59E-09	1%	
11/11	755	55200	366.29	15.44	1.19E-09	-0.06	1.09E-09	1.2	1.30E-09	60.52	1.58E-09	1%	
11/11	1357	21720	372.32	15.06	1.67E-09	-0.06	1.41E-09	1.2	1.69E-09	61.75	1.58E-09	0%	END TEST

END OF TEST TSB-7 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-8 STAGE TWO
Geometric factor - G = 0.008459"
Depth factor = 237.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1.wa)	Comments
10/27	1110	0	0.00	34.88	-	-	-	-	-	0	-	-	START
10/27	1422	11520	3.20	25.63	4.93E-08	-0.13	4.86E-08	1.1	5.34E-08	29.76	5.34E-08	-	
10/27	1606	6240	4.93	21.00	4.88E-08	0.13	4.81E-08	1.1	5.29E-08	44.66	5.33E-08	0%	
10/28	815	58140	21.08	30.89	4.88E-08	0.00	4.81E-08	1.1	5.29E-08	112.23	5.30E-08	0%	Dry Refill
10/28	1341	19560	26.52	18.81	3.81E-08	-0.03	3.80E-08	1.1	4.18E-08	150.45	5.07E-08	4%	
10/28	1750	14940	30.67	12.31	2.83E-08	-0.12	2.77E-08	1.1	3.05E-08	171.37	4.80E-08	6%	
10/28	1755	300	30.75	34.88	2.83E-08	0.00	2.77E-08	1.1	3.05E-08	171.37	4.79E-08	0%	Refill
10/29	755	50400	44.75	8.94	3.26E-08	-0.13	3.25E-08	1.1	3.57E-08	254.83	4.41E-08	8%	
10/29	800	300	44.83	35.69	3.26E-08	0.00	3.25E-08	1.1	3.58E-08	254.83	4.41E-08	0%	Refill
10/29	1203	14580	48.88	26.31	3.94E-08	0.00	3.94E-08	1.1	4.33E-08	285.01	4.40E-08	0%	
10/29	1646	16980	53.60	17.81	3.17E-08	0.13	3.22E-08	1.1	3.54E-08	312.36	4.33E-08	2%	
10/29	1648	120	53.63	35.31	3.17E-08	0.00	3.22E-08	1.1	3.54E-08	312.36	4.33E-08	0%	Refill
10/30	850	57720	69.67	9.75	2.80E-08	0.00	2.80E-08	1.1	3.08E-08	394.60	4.04E-08	7%	
10/30	852	120	69.70	31.19	2.80E-08	0.00	2.80E-08	1.1	3.08E-08	394.60	4.04E-08	0%	Refill
10/30	1229	13020	73.32	25.56	2.67E-08	-0.19	2.58E-08	1.1	2.84E-08	412.72	3.98E-08	1%	
10/30	1631	14520	77.35	17.88	3.35E-08	0.00	3.35E-08	1.1	3.69E-08	437.43	3.96E-08	0%	
10/30	1635	240	77.42	35.69	3.35E-08	0.00	3.35E-08	1.1	3.69E-08	437.43	3.96E-08	0%	Refill
10/31	801	55500	92.83	7.88	3.18E-08	-0.06	3.17E-08	1.1	3.49E-08	526.91	3.89E-08	2%	
10/31	806	300	92.92	35.88	3.18E-08	0.00	3.17E-08	1.1	3.49E-08	526.91	3.89E-08	0%	Refill
10/31	1208	14520	96.95	26.50	3.95E-08	-0.13	3.90E-08	1.1	4.29E-08	557.09	3.90E-08	0%	
10/31	1546	13080	100.58	19.88	3.19E-08	0.00	3.19E-08	1.1	3.51E-08	578.39	3.89E-08	0%	
10/31	1550	240	100.65	35.63	3.19E-08	0.00	3.19E-08	1.1	3.51E-08	578.39	3.89E-08	0%	Refill
11/01	1011	66060	119.00	5.06	2.95E-08	-0.19	2.93E-08	1.1	3.23E-08	676.75	3.79E-08	3%	
11/01	1013	120	119.03	35.75	2.95E-08	0.00	2.93E-08	1.1	3.22E-08	676.75	3.79E-08	0%	Refill
11/01	1533	19200	124.37	24.44	3.62E-08	0.07	3.64E-08	1.1	4.01E-08	713.14	3.80E-08	0%	
11/01	1537	240	124.43	35.00	3.62E-08	0.00	3.64E-08	1.1	4.00E-08	713.14	3.80E-08	0%	Refill
11/02	849	61920	141.63	4.25	3.18E-08	0.25	3.21E-08	1.1	3.53E-08	812.08	3.76E-08	1%	
11/02	851	120	141.67	33.13	3.18E-08	0.00	3.21E-08	1.1	3.53E-08	812.08	3.76E-08	0%	Refill
11/02	1342	17460	146.52	20.50	4.50E-08	-0.07	4.47E-08	1.1	4.92E-08	852.72	3.80E-08	1%	
11/02	1615	9180	149.07	15.50	3.50E-08	0.13	3.60E-08	1.1	3.96E-08	868.81	3.80E-08	0%	
11/02	1618	180	149.12	35.56	3.50E-08	0.00	3.60E-08	1.1	3.96E-08	868.81	3.80E-08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-8 STAGE TWO
Geometric factor - G = 0.006459"
Depth factor = 237.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1 wa)	Comments
11/03	819	57660	165.13	4.13	3.49E-08	0.12	3.50E-08	1.1	3.85E-08	969.94	3.81E-08	0%	
11/03	820	60	165.15	35.25	3.49E-08	0.00	3.50E-08	1.1	3.85E-08	969.94	3.81E-08	0%	Refill
11/03	1105	9900	167.90	28.69	4.04E-08	0.00	4.04E-08	1.1	4.45E-08	991.05	3.82E-08	0%	
11/03	1526	15660	172.25	19.75	3.59E-08	0.25	3.69E-08	1.1	4.06E-08	1019.81	3.82E-08	0%	
11/03	1556	1800	172.75	18.50	4.45E-08	0.25	5.34E-08	1.1	5.87E-08	1023.83	3.83E-08	0%	
11/03	1557	60	172.77	36.00	4.45E-08	0.00	5.34E-08	1.1	5.87E-08	1023.83	3.83E-08	0%	Refill
11/04	836	59940	189.42	2.63	3.57E-08	0.00	3.57E-08	1.1	3.93E-08	1131.20	3.84E-08	0%	
11/04	840	240	189.48	35.88	3.57E-08	0.00	3.57E-08	1.1	3.93E-08	1131.20	3.84E-08	0%	Refill
11/04	1645	29100	197.57	17.00	4.04E-08	0.07	4.06E-08	1.1	4.46E-08	1191.95	3.86E-08	1%	
11/04	1646	60	197.58	35.75	4.04E-08	0.00	4.06E-08	1.1	4.47E-08	1191.95	3.86E-08	0%	Refill
11/05	840	57240	213.48	3.63	3.59E-08	0.00	3.59E-08	1.1	3.95E-08	1295.30	3.87E-08	0%	
11/05	842	120	213.52	35.50	3.59E-08	0.00	3.59E-08	1.1	3.95E-08	1295.30	3.87E-08	0%	Refill
11/05	1352	18600	218.68	22.81	4.21E-08	0.00	4.21E-08	1.1	4.63E-08	1338.13	3.89E-08	0%	
11/05	1656	11040	221.75	18.69	3.54E-08	0.06	3.58E-08	1.1	3.94E-08	1355.82	3.89E-08	0%	
11/05	1657	60	221.77	35.31	3.54E-08	0.00	3.58E-08	1.1	3.94E-08	1355.82	3.89E-08	0%	Refill
11/06	835	56280	237.40	5.00	3.44E-08	0.06	3.45E-08	1.1	3.79E-08	1453.35	3.88E-08	0%	
11/06	837	120	237.43	35.75	3.44E-08	0.00	3.45E-08	1.1	3.80E-08	1453.35	3.88E-08	0%	Refill
11/06	1712	30900	246.02	16.19	3.95E-08	0.00	3.95E-08	1.1	4.35E-08	1516.29	3.90E-08	0%	
11/06	1713	60	246.03	35.88	3.95E-08	0.00	3.95E-08	1.1	4.35E-08	1516.29	3.90E-08	0%	Refill
11/07	837	55440	261.43	4.19	3.65E-08	-0.06	3.65E-08	1.1	4.01E-08	1618.26	3.91E-08	0%	
11/07	838	60	261.45	35.75	3.65E-08	0.00	3.65E-08	1.1	4.02E-08	1618.26	3.91E-08	0%	Refill
11/07	1618	27600	269.12	18.31	3.93E-08	0.06	3.94E-08	1.1	4.34E-08	1674.37	3.92E-08	0%	
11/07	1620	120	269.15	36.00	3.93E-08	0.00	3.94E-08	1.1	4.33E-08	1674.37	3.92E-08	0%	Refill
11/08	903	60180	285.87	2.00	3.63E-08	0.07	3.63E-08	1.1	4.00E-08	1783.77	3.92E-08	0%	
11/08	904	60	285.88	34.38	3.63E-08	0.00	3.63E-08	1.1	3.99E-08	1783.77	3.92E-08	0%	Refill
11/08	1619	26100	293.13	14.88	4.69E-08	0.12	4.72E-08	1.1	5.19E-08	1846.51	3.95E-08	1%	
11/08	1620	60	293.15	35.88	4.69E-08	0.00	4.72E-08	1.1	5.19E-08	1846.51	3.95E-08	0%	Refill
11/09	749	55740	308.63	35.81	4.69E-08	0.00	4.72E-08	1.1	5.19E-08	1961.96	4.02E-08	2%	-.25" Refill
11/09	1640	31860	317.48	13.44	4.41E-08	-0.13	4.38E-08	1.1	4.82E-08	2033.94	4.04E-08	1%	
11/09	1641	60	317.50	35.38	4.41E-08	0.00	4.38E-08	1.1	4.82E-08	2033.94	4.04E-08	0%	Refill
11/10	745	54240	332.57	4.19	3.68E-08	0.00	3.68E-08	1.1	4.05E-08	2134.30	4.04E-08	0%	
11/10	746	60	332.58	35.88	3.68E-08	0.00	3.68E-08	1.1	4.05E-08	2134.30	4.04E-08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-8 STAGE TWO
Geometric factor - G = 0.006459"
Depth factor = 237.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/10	1636	31800	341.42	16.69	3.76E-08	-0.19	3.72E-08	1.1	4.10E-08	2196.05	4.04E-08	0%	
11/10	1637	60	341.43	35.61	3.76E-08	0.00	3.72E-08	1.1	4.09E-08	2196.05	4.04E-08	0%	Refill
11/11	756	55140	356.75	6.25	3.41E-08	0.00	3.41E-08	1.1	3.75E-08	2291.16	4.03E-08	0%	
11/11	757	60	356.77	34.94	3.41E-08	0.00	3.41E-08	1.1	3.75E-08	2291.16	4.03E-08	0%	Refill
11/11	1356	21660	362.76	22.50	3.55E-08	0.00	3.55E-08	1.1	3.90E-08	2331.19	4.03E-08	0%	END TEST

END OF TEST TSB-8 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-9 STAGE TWO
Geometric factor – G = 0.006699"
Depth factor = 160.00"
TC values from Replacement TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	945	0	0.00	31.25	-	-	-	1.1	-	0	-	-	START
10/27	950	300	0.08	22.55	2.64E-06	0.06	2.66E-06	1.1	2.93E-06	27.99	2.93E-06	200%	
10/27	1000	600	0.25	13.13	1.50E-06	0.06	1.51E-06	1.1	1.66E-06	58.32	2.08E-06	34%	
10/27	1010	600	0.42	6.75	1.50E-06	0.06	1.51E-06	1.1	1.66E-06	78.83	1.92E-06	8%	
10/27	1020	600	0.58	1.25	9.51E-07	0.06	9.62E-07	1.1	1.06E-06	96.53	1.87E-06	14%	
10/27	1021	60	0.60	1.00	4.40E-07	0.06	5.46E-07	1.1	6.00E-07	97.33	1.84E-06	2%	
10/27	1407	13560	4.37	35.25	4.40E-07	0.00	5.46E-07	1.1	6.01E-07	100.55	7.43E-07	75%	Dry refill
10/27	1443	2160	4.97	21.25	5.86E-07	-0.13	5.80E-07	1.1	6.39E-07	145.60	7.31E-07	2%	
10/27	1601	4680	6.27	34.75	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	213.97	7.12E-07	3%	Dry refill
10/28	804	57780	22.32	32.25	5.86E-07	0.00	5.80E-07	1.2	6.96E-07	325.78	7.00E-07	2%	Dry refill
10/28	1125	12060	25.67	32.75	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	429.55	6.92E-07	1%	Dry refill
10/28	1335	7800	27.83	33.50	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	534.93	6.88E-07	1%	Dry refill
10/28	1745	15000	32.00	35.50	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	642.72	6.81E-07	1%	Dry refill
10/29	815	52200	46.50	35.00	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	756.94	6.86E-07	2%	Dry refill
10/29	1150	12900	50.08	34.19	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	869.56	6.86E-07	0%	Dry refill
10/29	1620	16200	54.58	35.25	5.86E-07	0.00	5.80E-07	1.1	6.38E-07	979.57	6.83E-07	0%	Dry refill
10/30	832	58320	70.78	35.00	5.86E-07	0.00	5.80E-07	1.2	6.98E-07	1092.99	6.71E-07	1%	Dry refill
10/30	1217	13500	58.33	9.69	1.75E-07	-0.19	1.74E-07	1.2	2.09E-07	1174.42	6.34E-07	5%	
10/30	1222	300	58.42	35.63	1.75E-07	0.00	1.74E-07	1.2	2.09E-07	1174.42	6.34E-07	0%	Refill
10/30	1616	14016	62.31	10.13	3.21E-08	0.00	3.20E-08	1.1	3.52E-08	1256.47	5.96E-07	8%	
10/31	747	55860	77.83	33.50	3.21E-08	0.00	3.20E-08	1.1	3.52E-08	1289.06	4.84E-07	21%	Dry refill
10/31	1157	15000	81.99	6.38	1.71E-07	-0.12	1.70E-07	1.1	1.88E-07	1376.32	4.69E-07	3%	
10/31	1204	420	82.11	34.88	1.71E-07	0.00	1.70E-07	1.1	1.87E-07	1376.32	4.69E-07	0%	Refill
10/31	1527	12180	85.49	11.56	1.78E-07	0.00	1.78E-07	1.1	1.96E-07	1451.35	4.58E-07	2%	
10/31	1528	60	85.51	35.00	1.78E-07	0.00	1.78E-07	1.1	1.96E-07	1451.35	4.58E-07	0%	Refill
11/01	958	66600	104.01	34.63	1.78E-07	0.00	1.78E-07	1.1	1.96E-07	1563.97	4.11E-07	11%	Dry refill
11/01	1530	19920	109.54	33.50	1.78E-07	0.00	4.97E-09	1.1	1.96E-07	1675.39	4.01E-07	3%	Dry refill
11/01	1602	1920	110.08	25.63	3.68E-07	0.00	3.68E-07	1.1	4.05E-07	1700.71	4.01E-07	0%	
11/02	834	59520	126.61	32.06	3.68E-07	0.00	3.68E-07	1.1	4.05E-07	1783.18	4.01E-07	0%	Dry refill
11/02	1350	18960	131.88	33.50	3.68E-07	0.00	3.68E-07	1.2	4.42E-07	1886.34	4.03E-07	0%	Dry refill
11/02	1400	600	132.04	32.19	1.93E-07	-0.05	1.85E-07	1.2	2.22E-07	1890.55	4.02E-07	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-9 STAGE TWO
Geometric factor -- G = 0.006699"
Depth factor = 160.00"
TC values from Replacement TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/02	1410	600	132.04	30.63	2.31E-07	-0.03	2.27E-07	1.2	2.72E-07	1895.57	4.03E-07	0%	
11/02	1420	600	132.21	29.31	1.97E-07	-0.01	1.96E-07	1.2	2.35E-07	1899.82	4.02E-07	0%	
11/02	1430	600	132.38	27.94	2.06E-07	0.01	2.07E-07	1.2	2.49E-07	1904.23	4.02E-07	0%	
11/02	1440	600	132.54	26.63	1.96E-07	0.03	2.03E-07	1.2	2.44E-07	1908.44	4.02E-07	0%	
11/02	1450	600	132.71	25.25	2.10E-07	0.05	2.18E-07	1.2	2.62E-07	1912.88	4.02E-07	0%	
11/02	1500	600	132.88	22.69	3.95E-07	0.07	4.06E-07	1.2	4.87E-07	1921.12	4.02E-07	0%	
11/02	1518	1080	133.18	22.00	5.96E-08	0.09	6.74E-08	1.2	8.09E-08	1923.34	4.01E-07	0%	
11/02	1530	720	133.38	20.56	1.88E-07	0.11	2.02E-07	1.2	2.43E-07	1927.97	4.01E-07	0%	
11/02	1550	1200	133.71	17.94	2.07E-07	0.13	2.18E-07	1.2	2.61E-07	1936.40	4.01E-07	0%	
11/02	1600	600	133.88	17.13	1.29E-07	0.13	1.50E-07	1.2	1.80E-07	1939.01	4.00E-07	0%	
11/02	1602	120	133.91	35.75	1.29E-07	0.00	1.50E-07	1.2	1.80E-07	1939.01	4.00E-07	0%	Refill
11/03	836	59640	150.48	36.00	1.29E-07	0.00	1.50E-07	1.2	1.80E-07	2054.04	3.76E-07	6%	Dry refill
11/03	1057	8460	152.83	19.63	1.75E-07	0.00	1.75E-07	1.2	2.10E-07	2106.71	3.73E-07	1%	
11/03	1545	17280	157.63	35.50	1.75E-07	0.00	1.75E-07	1.2	2.10E-07	2169.87	3.68E-07	1%	Dry refill
11/04	854	61740	174.78	34.56	1.75E-07	0.00	1.75E-07	1.2	2.10E-07	2284.10	3.53E-07	4%	Dry refill
11/04	1226	12720	178.31	11.13	1.72E-07	-0.06	1.71E-07	1.2	2.05E-07	2359.49	3.50E-07	1%	
11/04	1230	240	178.38	35.88	1.72E-07	0.00	1.71E-07	1.2	2.05E-07	2359.49	3.50E-07	0%	Refill
11/04	1623	13980	182.26	10.56	1.68E-07	0.13	1.69E-07	1.2	2.03E-07	2440.96	3.47E-07	1%	
11/04	1625	120	182.29	35.63	1.68E-07	0.00	1.69E-07	1.2	2.03E-07	2440.96	3.47E-07	0%	Refill
11/05	822	57420	198.24	33.50	1.68E-07	0.00	1.69E-07	1.2	2.03E-07	2555.60	3.35E-07	3%	Dry refill
11/05	1345	19380	203.63	2.31	1.54E-07	0.00	1.54E-07	1.2	1.85E-07	2655.96	3.31E-07	1%	
11/05	1346	60	203.64	35.75	1.54E-07	0.00	1.54E-07	1.2	1.85E-07	2655.96	3.31E-07	0%	Refill
11/05	1640	10440	206.54	16.81	1.66E-07	0.12	1.67E-07	1.2	2.00E-07	2716.90	3.29E-07	1%	
11/05	1641	60	206.56	35.81	1.66E-07	0.00	1.67E-07	1.2	2.00E-07	2716.90	3.29E-07	0%	Refill
11/06	820	56340	222.21	34.75	1.66E-07	0.00	1.67E-07	1.2	2.00E-07	2832.12	3.20E-07	3%	Dry refill
11/06	1412	21120	228.08	0.81	1.54E-07	-0.06	1.54E-07	1.2	1.85E-07	2941.33	3.17E-07	1%	
11/06	1413	60	228.09	35.94	1.54E-07	0.00	1.54E-07	1.2	1.85E-07	2941.33	3.17E-07	0%	Refill
11/06	1700	10020	230.88	18.13	1.62E-07	0.00	1.62E-07	1.2	1.94E-07	2998.64	3.15E-07	0%	
11/06	1701	60	230.89	35.88	1.62E-07	0.00	1.62E-07	1.2	1.94E-07	2998.64	3.15E-07	0%	Refill
11/07	848	56820	246.68	35.75	1.62E-07	0.00	1.62E-07	1.25	2.03E-07	3114.09	3.08E-07	2%	Dry refill
11/07	1414	19560	252.11	4.81	1.50E-07	-0.38	1.48E-07	1.2	1.77E-07	3213.64	3.05E-07	1%	
11/07	1415	60	252.13	35.75	1.50E-07	0.00	1.48E-07	1.2	1.78E-07	3213.64	3.05E-07	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-9 STAGE TWO
Geometric factor - G = 0.006699"
Depth factor = 160.00"
TC values from Replacement TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/07	1632	6220	254.41	21.63	1.55E-07	0.13	1.56E-07	1.2	1.88E-07	3259.07	3.04E-07	0%	
11/07	1633	60	254.43	35.88	1.55E-07	0.00	1.56E-07	1.2	1.87E-07	3259.07	3.04E-07	0%	Refill
11/08	857	59040	270.83	34.19	1.55E-07	0.00	1.55E-07	1.25	1.94E-07	3374.52	2.98E-07	2%	Dry refill
11/08	1328	16260	275.34	9.25	1.44E-07	-1.00	1.38E-07	1.2	1.65E-07	3454.76	2.95E-07	1%	
11/08	1329	60	275.36	35.81	1.44E-07	0.00	1.38E-07	1.2	1.66E-07	3454.76	2.95E-07	0%	Refill
11/08	1630	10860	278.38	18.50	1.45E-07	0.19	1.47E-07	1.2	1.76E-07	3510.48	2.94E-07	0%	
11/08	1631	60	278.39	35.88	1.45E-07	0.00	1.47E-07	1.2	1.76E-07	3510.48	2.94E-07	0%	Refill
11/09	738	54420	293.51	34.13	1.45E-07	0.00	1.47E-07	1.2	1.76E-07	3625.91	2.88E-07	2%	Dry refill
11/09	1347	22140	299.66	3.06	1.34E-07	-0.32	1.33E-07	1.2	1.59E-07	3725.88	2.85E-07	1%	
11/09	1348	60	299.68	35.63	1.34E-07	0.00	1.33E-07	1.2	1.60E-07	3725.88	2.85E-07	0%	Refill
11/09	1649	10860	302.69	18.00	1.48E-07	0.13	1.49E-07	1.2	1.79E-07	3762.61	2.84E-07	0%	
11/09	1650	60	302.71	35.50	1.48E-07	0.00	1.49E-07	1.2	1.79E-07	3762.61	2.84E-07	0%	Refill
11/10	751	54060	317.73	34.63	1.48E-07	0.00	1.49E-07	1.2	1.79E-07	3896.63	2.79E-07	2%	Dry Refill
11/10	1354	21780	323.78	4.56	1.31E-07	-0.25	1.30E-07	1.2	1.56E-07	3993.59	2.77E-07	1%	
11/10	1356	120	323.81	35.56	1.31E-07	0.00	1.30E-07	1.2	1.56E-07	3993.59	2.77E-07	0%	Refill
11/10	1645	10140	326.63	20.25	1.37E-07	-0.06	1.36E-07	1.2	1.63E-07	4042.85	2.76E-07	0%	
11/10	1646	60	326.64	36.00	1.37E-07	0.00	1.36E-07	1.2	1.63E-07	4042.85	2.76E-07	0%	Refill
11/11	747	54060	341.66	34.75	1.37E-07	0.00	1.36E-07	1.2	1.63E-07	4158.68	2.71E-07	2%	Dry Refill
11/11	930	6180	343.38	25.44	1.35E-07	-0.02	1.35E-07	1.2	1.61E-07	4188.84	2.70E-07	0%	
11/11	936	360	343.48	26.88	1.35E-07	0.00	1.35E-07	1.2	1.62E-07	4188.84	2.70E-07	0%	DYE Refill
11/11	1408	16320	348.01	6.06	1.23E-07	-0.06	1.23E-07	1.2	1.47E-07	4255.63	2.69E-07	1%	
11/11	1412	240	348.08	35.56	1.23E-07	0.00	1.23E-07	1.2	1.48E-07	4255.63	2.69E-07	0%	END TEST (Refill)

END OF TEST TSB-9 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-10 STAGE TWO
Geometric factor – G = 0.006634"
Depth factor = 165.25"
TC values from Replacement TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rl	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	915	0	0.00	33.00	–	–	–	–	–	0	–	–	START
10/27	1410	17700	4.92	27.63	2.37E–08	–0.31	2.23E–08	1.1	2.46E–08	17.28	2.46E–08	200%	
10/27	1555	6300	6.67	24.00	4.60E–08	0.13	4.77E–08	1.1	5.24E–08	28.98	3.19E–08	26%	
10/28	805	58200	22.83	33.50	4.60E–08	0.00	4.77E–08	1.2	5.72E–08	106.16	4.98E–08	44%	Dry Refill
10/28	1332	19620	28.28	15.56	7.35E–08	–0.06	7.32E–08	1.1	8.06E–08	163.90	5.58E–08	11%	
10/28	1736	14640	32.35	4.44	6.56E–08	0.25	6.71E–08	1.1	7.38E–08	199.66	5.80E–08	4%	
10/28	1740	240	32.42	35.00	6.56E–08	0.00	6.71E–08	1.1	7.38E–08	199.66	5.81E–08	0%	Refill
10/29	820	52800	47.08	35.31	6.56E–08	0.00	6.71E–08	1.1	7.38E–08	312.30	6.30E–08	8%	Dry Refill
10/29	1148	12480	50.55	22.88	7.83E–08	0.00	7.83E–08	1.1	8.62E–08	352.29	6.46E–08	2%	
10/29	1625	16620	55.17	12.50	5.19E–08	0.06	5.22E–08	1.1	5.74E–08	365.69	6.40E–08	1%	
10/29	1628	180	55.22	35.63	5.19E–08	0.00	5.22E–08	1.1	5.74E–08	365.69	6.39E–08	0%	Refill
10/30	836	58080	71.35	32.81	5.19E–08	0.00	5.22E–08	1.2	6.26E–08	500.33	6.37E–08	0%	Dry Refill
10/30	1216	13200	75.02	15.75	1.04E–07	–0.19	1.03E–07	1.2	1.23E–07	555.23	6.66E–08	4%	
10/30	1220	240	75.08	32.81	1.04E–07	0.00	1.03E–07	1.2	1.24E–07	555.23	6.66E–08	0%	Refill
10/30	1615	14100	79.00	15.94	9.62E–08	0.00	9.62E–08	1.1	1.06E–07	609.51	6.86E–08	3%	
10/30	1627	720	79.20	34.75	9.62E–08	0.00	9.62E–08	1.1	1.06E–07	609.51	6.87E–08	0%	Refill
10/31	746	55140	94.52	31.25	9.62E–08	0.00	9.62E–08	1.1	1.06E–07	721.32	7.47E–08	8%	Dry Refill
10/31	1158	15120	98.72	15.06	8.66E–08	–0.12	8.60E–08	1.1	9.45E–08	773.41	7.55E–08	1%	
10/31	1205	420	98.83	35.38	8.66E–08	0.00	8.60E–08	1.1	9.46E–08	773.41	7.55E–08	0%	Refill
10/31	1527	12120	102.20	21.06	9.33E–08	0.00	9.33E–08	1.1	1.03E–07	819.49	7.64E–08	1%	
10/31	1535	480	102.33	35.63	9.33E–08	0.00	9.33E–08	1.1	1.03E–07	819.49	7.65E–08	0%	Refill
11/01	1002	66420	120.78	35.81	9.33E–08	0.00	9.33E–08	1.1	1.03E–07	934.13	8.05E–08	5%	Dry refill
11/01	1526	19440	126.18	18.13	7.23E–08	0.00	7.23E–08	1.1	7.95E–08	991.02	8.04E–08	0%	
11/02	837	61860	143.37	31.44	7.23E–08	0.00	7.23E–08	1.1	7.95E–08	1049.36	8.03E–08	0%	Dry Refill
11/02	1335	17880	148.33	16.63	6.67E–08	–0.07	6.64E–08	1.2	7.97E–08	1097.01	8.03E–08	0%	
11/02	1600	8700	150.75	10.88	5.60E–08	0.13	5.73E–08	1.2	6.87E–08	1115.51	8.01E–08	0%	
11/02	1603	180	150.80	35.25	5.60E–08	0.00	5.73E–08	1.2	6.88E–08	1115.51	8.01E–08	0%	Refill
11/03	838	59700	167.38	35.81	5.60E–08	0.00	5.73E–08	1.2	6.88E–08	1228.93	7.90E–08	1%	Dry refill
11/03	1058	8400	169.72	28.19	7.04E–08	0.00	7.04E–08	1.2	8.44E–08	1253.45	7.91E–08	0%	
11/03	1548	17400	174.55	13.75	6.78E–08	0.32	6.94E–08	1.2	8.33E–08	1299.91	7.92E–08	0%	
11/03	1550	120	169.75	35.75	6.78E–08	0.00	6.94E–08	1.2	8.33E–08	1299.91	7.91E–08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-10 STAGE TWO
Geometric factor – G = 0.006634"
Depth factor = 165.25"
TC values from Replacement TEG-1

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/04	858	61680	186.88	34.06	6.78E-08	0.00	6.94E-08	1.2	8.33E-08	1414.94	7.94E-08	0%	Dry refill
11/04	1231	12780	190.43	22.63	7.06E-08	-0.06	7.02E-08	1.2	8.42E-08	1451.72	7.95E-08	0%	
11/04	1626	14100	194.35	11.56	6.54E-08	0.13	6.62E-08	1.2	7.94E-08	1487.34	7.95E-08	0%	
11/04	1628	120	194.38	34.81	6.54E-08	0.00	6.62E-08	1.2	7.94E-08	1487.34	7.95E-08	0%	Refill
11/05	825	57420	210.33	35.31	6.54E-08	0.00	6.62E-08	1.2	7.94E-08	1599.34	7.95E-08	0%	Dry refill
11/05	1347	19320	215.70	18.69	6.83E-08	0.00	6.83E-08	1.2	8.20E-08	1652.82	7.96E-08	0%	
11/05	1644	10620	218.65	11.06	6.05E-08	0.12	6.15E-08	1.2	7.38E-08	1677.37	7.95E-08	0%	
11/05	1645	120	218.68	35.50	6.05E-08	0.00	6.15E-08	1.2	7.38E-08	1677.37	7.95E-08	0%	Refill
11/06	823	56220	234.30	35.75	6.05E-08	0.00	6.15E-08	1.2	7.38E-08	1791.59	7.91E-08	0%	Dry refill
11/06	1416	21180	240.18	18.44	6.49E-08	-0.06	6.47E-08	1.2	7.76E-08	1847.29	7.91E-08	0%	
11/06	1703	10020	242.97	11.00	6.26E-08	0.00	6.26E-08	1.2	7.51E-08	1871.23	7.90E-08	0%	
11/06	1704	60	242.98	35.56	6.26E-08	0.00	6.26E-08	1.2	7.51E-08	1871.23	7.90E-08	0%	Refill
11/07	852	56880	258.78	36.00	6.26E-08	0.00	6.26E-08	1.2	7.51E-08	1965.65	7.88E-08	0%	Dry refill
11/07	1417	19500	264.20	23.25	5.13E-08	-0.38	4.97E-08	1.2	5.97E-08	2026.67	7.84E-08	0%	
11/07	1635	8280	266.50	18.63	4.56E-08	0.13	4.69E-08	1.2	5.63E-08	2041.54	7.82E-08	0%	
11/07	1636	60	266.52	36.00	4.56E-08	0.00	4.69E-08	1.2	5.63E-08	2041.54	7.82E-08	0%	Refill
11/08	853	58620	282.80	3.50	4.57E-08	0.18	4.59E-08	1.25	5.74E-08	2146.11	7.70E-08	2%	
11/08	854	60	282.82	35.50	4.57E-08	0.00	4.59E-08	1.25	5.74E-08	2146.11	7.70E-08	0%	Refill
11/08	1331	16620	287.43	25.56	4.67E-08	-1.00	4.19E-08	1.2	5.03E-08	2178.09	7.66E-08	1%	
11/08	1632	10860	290.45	20.00	4.15E-08	0.19	4.29E-08	1.2	5.15E-08	2195.98	7.63E-08	0%	
11/08	1633	60	290.47	35.63	4.15E-08	0.00	4.29E-08	1.2	5.15E-08	2195.98	7.63E-08	0%	Refill
11/09	739	54360	305.57	8.56	4.05E-08	0.13	4.07E-08	1.2	4.89E-08	2283.08	7.50E-08	2%	
11/09	741	120	305.60	36.00	4.05E-08	0.00	4.07E-08	1.2	4.88E-08	2283.08	7.50E-08	0%	Refill
11/09	1651	33000	314.77	19.31	4.00E-08	-0.19	3.96E-08	1.2	4.75E-08	2336.78	7.42E-08	1%	
11/09	1652	60	314.78	36.00	4.00E-08	0.00	3.96E-08	1.2	4.75E-08	2336.78	7.42E-08	0%	Refill
11/10	752	54000	329.78	6.63	4.44E-08	0.06	4.45E-08	1.2	5.34E-08	2431.28	7.32E-08	1%	
11/10	753	60	329.80	36.00	4.44E-08	0.00	4.45E-08	1.2	5.34E-08	2431.28	7.32E-08	0%	Refill
11/10	1648	32100	338.72	17.13	4.68E-08	-0.31	4.60E-08	1.2	5.52E-08	2492.00	7.28E-08	1%	
11/10	1649	60	338.73	35.88	4.68E-08	0.00	4.60E-08	1.2	5.52E-08	2492.00	7.28E-08	0%	Refill
11/11	750	54060	353.75	9.31	3.99E-08	-0.06	3.98E-08	1.2	4.78E-08	2577.49	7.17E-08	1%	
11/11	751	60	353.77	36.00	3.99E-08	0.00	3.98E-08	1.2	4.78E-08	2577.49	7.17E-08	0%	Refill
11/11	1413	22920	360.13	24.38	3.97E-08	-0.06	3.95E-08	1.2	4.73E-08	2614.88	7.13E-08	1%	END TEST

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-11 STAGE TWO
Geometric factor - G = 0.006576"
Depth factor = 234.75"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/27	859	0	0.00	35.25	-	-	-	-	-	0.00	-	-	START
10/27	1411	18720	5.20	31.56	1.23E-08	-0.13	1.18E-08	1.1	1.30E-08	11.87	1.30E-08	-	
10/27	1559	6480	7.00	30.13	1.39E-08	0.13	1.51E-08	1.1	1.67E-08	16.47	1.40E-08	7%	
10/28	800	57660	23.02	17.50	1.42E-08	0.06	1.42E-08	1.1	1.56E-08	57.11	1.51E-08	8%	
10/28	1335	20100	28.60	14.38	1.03E-08	-0.03	1.02E-08	1.1	1.13E-08	67.15	1.44E-08	5%	
10/28	1737	14520	32.63	12.19	1.02E-08	-0.12	9.80E-09	1.1	1.06E-08	74.20	1.39E-08	3%	
10/29	811	52440	47.20	4.38	1.02E-08	-0.13	1.01E-08	1.1	1.11E-08	99.33	1.30E-08	6%	
10/29	825	240	47.27	33.00	1.02E-08	0.00	1.01E-08	1.1	1.11E-08	99.33	1.30E-08	0%	Refill
10/29	1149	12240	50.67	30.69	1.18E-08	0.00	1.18E-08	1.1	1.30E-08	106.76	1.30E-08	0%	
10/29	1630	16860	55.35	27.63	1.15E-08	0.13	1.20E-08	1.1	1.32E-08	116.61	1.30E-08	0%	
10/30	836	58080	71.48	17.50	1.13E-08	0.00	1.13E-08	1.1	1.25E-08	149.20	1.29E-08	1%	
10/30	1215	13020	75.10	15.19	1.18E-08	-0.19	1.08E-08	1.1	1.19E-08	156.64	1.29E-08	0%	
10/30	1614	14340	79.08	12.75	1.14E-08	0.00	1.14E-08	1.1	1.26E-08	164.49	1.28E-08	0%	
10/30	1625	660	79.27	35.81	1.14E-08	0.00	1.14E-08	1.1	1.25E-08	164.83	1.28E-08	0%	Refill
10/31	745	56960	95.65	25.50	1.10E-08	-0.06	1.09E-08	1.1	1.20E-08	198.01	1.27E-08	1%	
10/31	1158	15180	99.87	21.56	1.68E-08	-0.13	1.62E-08	1.1	1.79E-08	210.66	1.29E-08	2%	
10/31	1528	12600	103.37	19.25	1.20E-08	0.00	1.20E-08	1.1	1.32E-08	218.12	1.29E-08	0%	
11/01	950	65520	121.57	8.19	1.13E-08	-0.19	1.12E-08	1.1	1.23E-08	253.70	1.28E-08	1%	
11/01	1006	960	121.83	35.75	1.13E-08	0.00	1.12E-08	1.1	1.23E-08	260.05	1.28E-08	0%	Dry refill
11/01	1525	19140	127.15	31.75	1.30E-08	0.07	1.32E-08	1.1	1.46E-08	292.92	1.29E-08	1%	
11/02	822	61020	144.10	20.63	1.17E-08	0.25	1.19E-08	1.1	1.31E-08	328.70	1.29E-08	0%	
11/02	1334	18720	149.30	17.38	1.14E-08	-0.07	1.12E-08	1.1	1.23E-08	339.16	1.29E-08	0%	
11/02	1605	9060	151.82	15.25	1.56E-08	0.13	1.66E-08	1.1	1.83E-08	346.01	1.30E-08	1%	
11/03	834	59340	168.30	5.00	1.18E-08	0.12	1.19E-08	1.1	1.31E-08	379.00	1.30E-08	0%	
11/03	840	360	168.40	35.63	1.18E-08	0.00	1.19E-08	1.1	1.31E-08	379.19	1.30E-08	0%	Refill
11/03	1100	8400	170.73	33.88	1.29E-08	0.00	1.29E-08	1.1	1.42E-08	384.82	1.30E-08	0%	
11/03	1553	17580	175.62	30.31	1.27E-08	0.25	1.36E-08	1.1	1.50E-08	396.31	1.31E-08	0%	
11/04	851	61080	192.58	18.38	1.26E-08	0.00	1.26E-08	1.1	1.39E-08	434.70	1.31E-08	1%	
11/04	1232	13260	196.27	15.88	1.25E-08	0.00	1.25E-08	1.1	1.38E-08	442.74	1.32E-08	0%	
11/04	1621	13740	200.08	13.25	1.28E-08	0.07	1.32E-08	1.1	1.45E-08	451.20	1.32E-08	0%	
11/05	819	57480	216.05	3.50	1.17E-08	0.00	1.17E-08	1.1	1.28E-08	482.58	1.32E-08	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-11 STAGE TWO
Geometric factor - G = 0.006576"
Depth factor = 234.75"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	Kt	TC	KtC	visc. factor	KtCT	cumulative volume (cc)	K (twa)	RPD (Ktwa)	Comments
11/05	827	480	216.18	35.56	1.17E-08	0.00	1.17E-08	1.1	1.29E-08	482.84	1.32E-08	0%	Refill
11/05	1349	19320	221.55	31.25	1.39E-08	0.00	1.39E-08	1.1	1.53E-08	496.70	1.32E-08	0%	
11/05	1649	10080	224.35	29.00	1.41E-08	0.06	1.45E-08	1.1	1.59E-08	503.94	1.32E-08	0%	
11/06	822	55980	239.90	17.56	1.32E-08	0.06	1.33E-08	1.1	1.46E-08	540.75	1.33E-08	1%	
11/06	1417	21300	245.82	13.56	1.25E-08	-0.06	1.23E-08	1.1	1.36E-08	553.82	1.33E-08	0%	
11/06	1707	10200	248.65	11.75	1.20E-08	0.00	1.20E-08	1.1	1.32E-08	559.45	1.33E-08	0%	
11/06	1708	60	248.67	35.50	1.20E-08	0.00	1.20E-08	1.1	1.32E-08	559.48	1.33E-08	0%	Refill
11/07	853	56700	264.42	23.31	1.36E-08	-0.06	1.35E-08	1.1	1.49E-08	598.70	1.34E-08	1%	
11/07	1418	19500	269.83	19.38	1.31E-08	-0.13	1.27E-08	1.1	1.40E-08	611.35	1.34E-08	0%	
11/07	1627	7740	271.98	17.88	1.28E-08	0.06	1.33E-08	1.1	1.46E-08	616.17	1.34E-08	0%	
11/08	851	59040	288.38	7.00	1.25E-08	0.07	1.25E-08	1.1	1.38E-08	651.18	1.35E-08	0%	
11/08	852	60	288.40	35.50	1.25E-08	0.00	1.25E-08	1.1	1.38E-08	651.22	1.35E-08	0%	Refill
11/08	1332	16800	293.07	31.56	1.46E-08	-0.89	1.20E-08	1.1	1.32E-08	663.89	1.35E-08	0%	
11/08	1635	10980	296.12	29.44	1.22E-08	0.12	1.28E-08	1.1	1.41E-08	670.72	1.35E-08	0%	
11/09	743	54480	311.25	18.75	1.27E-08	-0.07	1.26E-08	1.1	1.38E-08	705.11	1.35E-08	0%	
11/09	1654	33060	320.43	12.69	1.22E-08	-0.13	1.20E-08	1.1	1.32E-08	724.61	1.35E-08	0%	
11/09	1655	60	320.45	36.00	1.22E-08	0.00	1.20E-08	1.1	1.32E-08	724.65	1.35E-08	0%	Refill
11/10	755	54000	335.45	25.00	1.28E-08	0.00	1.28E-08	1.1	1.41E-08	760.04	1.35E-08	0%	
11/10	1650	32100	344.37	18.81	1.26E-08	-0.19	1.22E-08	1.1	1.34E-08	779.98	1.35E-08	0%	
11/11	752	54120	359.40	9.31	1.18E-08	0.00	1.18E-08	1.1	1.30E-08	810.52	1.35E-08	0%	
11/11	1414	22920	365.77	5.56	1.13E-08	0.00	1.13E-08	1.1	1.24E-08	822.59	1.35E-08	0%	END TEST

END OF TEST TSB-11 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-12 STAGE TWO
Geometric factor - G = 0.006401"
Depth factor = 266.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	Kt	TC	KtC	visc. factor	KtCT	cumulative volume (cc)	K (twa)	RPD (Kt.wa)	Comments
10/26	1047	0	0.00	33.50	-	-	-	-	-	0.00	-	-	START
10/26	1130	2580	0.72	32.75	1.56E-08	-0.40	7.37E-09	1.1	8.11E-09	2.41	8.11E-09	-	
10/26	1500	12600	4.22	29.88	1.25E-08	-0.45	1.05E-08	1.1	1.15E-08	11.65	1.10E-08	30%	
10/26	1634	5640	5.78	27.75	2.08E-08	-0.50	1.59E-08	1.1	1.75E-08	18.50	1.27E-08	15%	
10/27	751	55020	21.07	0.69	2.86E-08	-0.25	2.83E-08	1.1	3.11E-08	105.57	2.61E-08	69%	
10/27	753	120	21.10	33.38	2.86E-08	0.00	2.83E-08	1.1	3.11E-08	105.76	2.61E-08	0%	Refill
10/27	1351	21480	27.07	18.69	3.81E-08	-0.13	3.77E-08	1.1	4.15E-08	153.03	2.95E-08	12%	
10/27	1612	8460	29.42	13.75	3.36E-08	0.13	3.45E-08	1.1	3.80E-08	168.92	3.02E-08	2%	
10/27	1627	300	29.50	34.50	3.36E-08	0.00	3.45E-08	1.1	3.80E-08	169.46	3.02E-08	0%	Refill
10/28	743	54960	44.77	1.25	3.47E-08	0.06	3.48E-08	1.1	3.82E-08	278.45	3.29E-08	9%	
10/28	820	2220	45.38	33.81	3.47E-08	0.00	3.48E-08	1.1	3.83E-08	280.80	3.30E-08	0%	Refill
10/28	1355	20100	50.97	20.13	3.78E-08	-0.03	3.77E-08	1.1	4.15E-08	324.62	3.39E-08	3%	
10/28	1716	12060	54.32	13.06	3.37E-08	-0.12	3.32E-08	1.1	3.65E-08	347.37	3.41E-08	0%	
10/28	1720	240	54.38	34.13	3.37E-08	0.00	3.32E-08	1.1	3.65E-08	347.81	3.41E-08	0%	Refill
10/29	740	51600	68.72	2.44	3.52E-08	-0.13	3.50E-08	1.1	3.85E-08	449.76	3.50E-08	3%	
10/29	835	3300	69.63	35.88	3.52E-08	0.00	3.50E-08	1.1	3.85E-08	455.91	3.51E-08	0%	Refill
10/29	1135	10800	72.63	28.00	3.98E-08	0.00	3.98E-08	1.1	4.38E-08	481.26	3.54E-08	1%	
10/29	1555	15600	76.97	18.06	3.56E-08	0.13	3.63E-08	1.1	4.00E-08	513.25	3.57E-08	1%	
10/29	1600	300	77.05	35.88	3.56E-08	0.00	3.63E-08	1.1	3.99E-08	513.85	3.57E-08	0%	Refill
10/30	800	57600	93.05	1.88	3.37E-08	0.00	3.37E-08	1.1	3.71E-08	623.25	3.59E-08	1%	
10/30	807	420	93.17	35.25	3.37E-08	0.00	3.37E-08	1.1	3.71E-08	624.04	3.59E-08	0%	Refill
10/30	1157	13800	97.00	25.81	3.75E-08	-0.19	3.67E-08	1.1	4.04E-08	654.41	3.61E-08	0%	
10/30	1545	13680	100.80	17.63	3.38E-08	0.00	3.38E-08	1.1	3.72E-08	680.73	3.61E-08	0%	
10/30	1549	240	100.87	35.38	3.38E-08	0.00	3.38E-08	1.1	3.72E-08	681.19	3.61E-08	0%	Refill
10/31	718	55740	116.35	2.75	3.34E-08	-0.06	3.34E-08	1.1	3.67E-08	786.18	3.62E-08	0%	
10/31	725	420	116.47	35.50	3.34E-08	0.00	3.34E-08	1.1	3.67E-08	786.96	3.62E-08	0%	Refill
10/31	1141	15360	120.73	25.06	3.73E-08	-0.13	3.68E-08	1.1	4.05E-08	820.55	3.64E-08	0%	
10/31	1501	12000	124.07	18.00	3.33E-08	0.00	3.33E-08	1.1	3.66E-08	843.27	3.64E-08	0%	
10/31	1509	480	124.20	35.38	3.33E-08	0.00	3.33E-08	1.1	3.66E-08	844.14	3.64E-08	0%	Refill
11/01	927	65880	142.50	33.00	3.33E-08	0.00	3.33E-08	1.1	3.66E-08	957.98	3.64E-08	0%	Dry refill
11/01	1456	19740	147.98	19.88	3.70E-08	0.07	3.72E-08	1.1	4.09E-08	1000.20	3.66E-08	0%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-12 STAGE TWO
Geometric factor - G = 0.008401"
Depth factor = 266.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	Kt	TC	KtC	visc. factor	KtCT	cumulative volume (cc)	K (twa)	RPD (Kt wa)	Comments
11/01	1507	660	146.17	35.44	3.70E-08	0.00	3.72E-08	1.1	4.09E-08	1001.56	3.66E-08	0%	Refill
11/02	754	60480	164.97	3.56	3.00E-08	0.25	3.03E-08	1.1	3.33E-08	1104.06	3.62E-08	1%	
11/02	802	480	165.10	35.38	3.00E-08	0.00	3.03E-08	1.1	3.33E-08	1104.86	3.62E-08	0%	Refill
11/02	1317	18900	170.35	24.00	3.31E-08	-0.07	3.29E-08	1.1	3.62E-08	1141.50	3.62E-08	0%	
11/02	1624	11220	173.47	18.19	2.93E-08	0.13	3.00E-08	1.1	3.30E-08	1160.19	3.62E-08	0%	
11/02	1628	240	173.53	35.63	2.93E-08	0.00	3.00E-08	1.1	3.30E-08	1160.59	3.62E-08	0%	Refill
11/03	755	55620	188.98	7.06	2.91E-08	0.12	2.92E-08	1.1	3.21E-08	1252.51	3.58E-08	1%	
11/03	800	300	189.07	35.88	2.91E-08	0.00	2.92E-08	1.1	3.21E-08	1253.01	3.58E-08	0%	Refill
11/03	1113	11580	192.28	29.50	3.00E-08	0.00	3.00E-08	1.1	3.30E-08	1273.53	3.58E-08	0%	
11/03	1503	13800	196.12	22.44	2.85E-08	0.25	2.95E-08	1.1	3.25E-08	1298.25	3.57E-08	0%	
11/04	805	61320	213.15	35.63	2.85E-08	0.00	2.85E-08	1.1	3.14E-08	1368.45	3.54E-08	1%	Dry refill
11/04	1215	15000	217.32	27.31	3.03E-08	0.00	3.03E-08	1.1	3.33E-08	1395.22	3.53E-08	0%	
11/04	1600	13500	221.07	20.69	2.75E-08	0.07	2.78E-08	1.1	3.06E-08	1416.52	3.53E-08	0%	
11/04	1650	3000	221.90	19.31	2.82E-08	0.07	2.75E-08	1.1	3.02E-08	1420.96	3.52E-08	0%	
11/04	1652	120	221.93	35.25	2.82E-08	0.00	2.75E-08	1.1	3.03E-08	1421.13	3.52E-08	0%	Refill
11/05	746	53640	236.83	10.06	2.65E-08	0.00	2.65E-08	1.1	2.91E-08	1502.19	3.49E-08	1%	
11/05	750	240	236.90	35.81	2.65E-08	0.00	2.65E-08	1.1	2.92E-08	1502.55	3.49E-08	0%	Refill
11/05	1332	20520	242.60	25.31	2.81E-08	0.00	2.81E-08	1.1	3.09E-08	1536.33	3.48E-08	0%	
11/05	1617	9900	245.35	20.88	2.52E-08	0.06	2.55E-08	1.1	2.81E-08	1550.59	3.47E-08	0%	
11/05	1618	60	245.37	35.88	2.52E-08	0.00	2.55E-08	1.1	2.81E-08	1550.67	3.47E-08	0%	Refill
11/06	755	56220	260.98	10.31	2.56E-08	0.06	2.57E-08	1.1	2.82E-08	1632.95	3.43E-08	1%	
11/06	758	180	261.03	35.56	2.56E-08	0.00	2.57E-08	1.1	2.83E-08	1633.21	3.43E-08	0%	Refill
11/06	1405	22020	267.15	24.75	2.70E-08	-0.06	2.68E-08	1.1	2.95E-08	1667.99	3.42E-08	0%	
11/06	1640	9300	269.73	20.69	2.46E-08	0.00	2.46E-08	1.1	2.70E-08	1681.05	3.41E-08	0%	
11/06	1642	120	269.77	35.75	2.46E-08	0.00	2.46E-08	1.1	2.71E-08	1681.22	3.41E-08	0%	Refill
11/07	825	56580	285.48	10.75	2.49E-08	-0.06	2.48E-08	1.1	2.73E-08	1761.66	3.37E-08	1%	
11/07	826	60	285.50	35.88	2.49E-08	0.00	2.48E-08	1.1	2.73E-08	1761.75	3.37E-08	0%	Refill
11/07	1358	19920	291.03	26.38	2.61E-08	-0.13	2.57E-08	1.1	2.83E-08	1792.31	3.36E-08	0%	
11/07	1640	5580	292.58	22.19	4.21E-08	0.06	4.27E-08	1.1	4.69E-08	1805.79	3.37E-08	0%	
11/07	1641	60	292.60	35.88	4.21E-08	0.00	4.27E-08	1.1	4.70E-08	1805.94	3.37E-08	0%	Refill
11/08	828	56820	308.38	12.19	2.34E-08	0.07	2.35E-08	1.1	2.58E-08	1882.16	3.33E-08	1%	
11/08	1315	17220	313.17	5.81	2.19E-08	-0.69	1.95E-08	1.1	2.15E-08	1902.69	3.31E-08	1%	

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-12 STAGE TWO
Geometric factor - G = 0.006401"
Depth factor = 266.00"
TC values from Replacement TEG-2

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/08	1316	60	313.18	36.00	2.19E-08	0.00	1.95E-08	1.1	2.15E-08	1902.76	3.31E-08	0%	Refill
11/08	1600	9840	315.92	31.63	2.41E-08	0.12	2.47E-08	1.1	2.72E-08	1916.82	3.31E-08	0%	
11/09	714	54840	331.15	10.44	2.19E-08	-0.07	2.18E-08	1.1	2.40E-08	1985.00	3.27E-08	1%	
11/09	715	60	331.17	35.94	2.19E-08	0.00	2.18E-08	1.1	2.40E-08	1985.08	3.27E-08	0%	Refill
11/09	1336	22860	337.52	25.94	2.40E-08	-0.19	2.35E-08	1.1	2.58E-08	2017.26	3.25E-08	0%	
11/09	1617	9660	340.20	22.13	2.21E-08	0.06	2.25E-08	1.1	2.47E-08	2029.51	3.25E-08	0%	
11/09	1618	60	340.22	35.75	2.21E-08	0.00	2.25E-08	1.1	2.48E-08	2029.59	3.25E-08	0%	Refill
11/10	721	54180	355.27	14.38	2.20E-08	0.00	2.20E-08	1.1	2.42E-08	2098.35	3.21E-08	1%	
11/10	723	120	355.30	35.81	2.20E-08	0.00	2.20E-08	1.1	2.42E-08	2098.50	3.21E-08	0%	Refill
11/10	1617	32040	364.20	22.63	2.27E-08	-0.19	2.23E-08	1.1	2.48E-08	2140.91	3.19E-08	1%	
11/10	1618	60	364.22	35.75	2.27E-08	0.00	2.23E-08	1.1	2.45E-08	2140.99	3.19E-08	0%	Refill
11/11	727	54540	379.37	14.88	2.14E-08	0.00	2.14E-08	1.1	2.35E-08	2208.14	3.16E-08	1%	
11/11	728	60	379.38	35.75	2.14E-08	0.00	2.14E-08	1.1	2.35E-08	2208.21	3.16E-08	0%	Refill
11/11	1338	22200	385.55	27.00	2.16E-08	0.00	2.16E-08	1.1	2.37E-08	2236.37	3.15E-08	0%	END TEST

END OF TEST TSB-12 STAGE TWO

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-13 STAGE TWO
Geometric factor – G = 0.006243"
Depth factor = 356.8"
TC values from TEG-3

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
10/26	1130	0	0.00	33.56	–	–	–	1.1	–	0.00	–	–	START
10/26	1502	12720	3.53	19.38	4.81E-08	0.06	4.63E-08	1.1	5.10E-08	45.83	5.10E-08	–	
10/26	1634	5520	5.07	12.81	5.06E-08	-0.06	5.01E-08	1.1	5.52E-08	66.77	5.22E-08	2%	
10/26	1636	120	5.10	35.25	5.06E-08	0.00	5.01E-08	1.1	5.51E-08	67.21	5.23E-08	0%	Refill
10/27	754	55080	20.40	34.88	5.06E-08	0.00	5.01E-08	1.1	5.51E-08	160.64	5.44E-08	4%	Dry refill
10/27	1352	21480	26.37	14.25	3.99E-08	-0.13	3.97E-08	1.1	4.37E-08	247.01	5.20E-08	5%	
10/27	1613	8460	28.72	7.31	3.54E-08	0.19	3.84E-08	1.1	4.00E-08	269.34	5.10E-08	2%	
10/27	1628	900	28.97	34.63	3.54E-08	0.00	3.84E-08	1.1	4.00E-08	271.49	5.09E-08	0%	Refill
10/28	746	55080	44.27	31.00	3.54E-08	0.00	3.84E-08	1.1	4.00E-08	382.92	4.71E-08	6%	Dry refill
10/28	1318	19920	49.80	9.00	4.65E-08	-0.31	4.58E-08	1.1	5.04E-08	453.70	4.75E-08	1%	
10/28	1400	2520	50.50	6.56	4.21E-08	0.06	4.32E-08	1.1	4.75E-08	461.56	4.75E-08	0%	
10/28	1725	12300	53.92	32.75	4.21E-08	0.00	4.32E-08	1.1	4.75E-08	482.66	4.75E-08	0%	Dry refill
10/29	840	54900	69.17	32.61	4.21E-08	0.00	4.32E-08	1.1	4.75E-08	566.04	4.75E-08	0%	Dry refill
10/29	1135	10500	72.08	20.44	4.67E-08	-0.06	4.65E-08	1.1	5.33E-08	627.84	4.77E-08	0%	
10/29	1556	15660	76.43	4.25	4.44E-08	0.12	4.48E-08	1.1	4.92E-08	679.93	4.78E-08	0%	
10/29	1600	240	76.50	35.56	4.44E-08	0.00	4.48E-08	1.1	4.93E-08	680.72	4.78E-08	0%	Refill
10/30	805	57900	92.58	35.75	4.44E-08	0.00	4.48E-08	1.1	4.93E-08	795.14	4.81E-08	1%	Dry refill
10/30	1159	14040	96.48	17.75	5.30E-08	-0.13	5.26E-08	1.1	5.79E-08	853.05	4.85E-08	1%	
10/30	1547	13680	100.28	2.25	4.90E-08	-0.06	4.88E-08	1.1	5.37E-08	902.93	4.87E-08	0%	
10/30	1553	360	100.38	35.38	4.90E-08	0.00	4.88E-08	1.1	5.37E-08	904.21	4.87E-08	0%	Refill
10/31	719	55560	115.82	33.50	4.90E-08	0.00	4.88E-08	1.1	5.37E-08	1018.05	4.93E-08	1%	Dry refill
10/31	1142	15780	120.20	10.00	6.24E-08	0.00	6.24E-08	1.1	6.86E-08	1093.66	5.00E-08	1%	
10/31	1145	180	120.25	35.38	6.24E-08	0.00	6.24E-08	1.1	6.86E-08	1094.51	5.01E-08	0%	Refill
10/31	1502	11820	123.53	15.00	7.16E-08	0.00	7.16E-08	1.1	7.88E-08	1160.09	5.08E-08	2%	
10/31	1508	360	123.63	35.06	7.16E-08	0.00	7.16E-08	1.1	7.88E-08	1162.02	5.08E-08	0%	Refill
11/01	928	66000	141.97	35.00	7.16E-08	0.00	7.16E-08	1.1	7.88E-08	1274.83	5.44E-08	7%	Dry refill
11/01	1500	19920	147.50	5.31	6.27E-08	0.00	6.27E-08	1.1	6.90E-08	1370.36	5.50E-08	1%	
11/01	1505	300	147.58	35.56	6.27E-08	0.00	6.27E-08	1.1	6.90E-08	1371.78	5.50E-08	0%	Refill
11/02	754	60540	164.40	33.00	6.27E-08	0.00	6.27E-08	1.1	6.90E-08	1486.20	5.64E-08	3%	Dry refill
11/02	1318	19440	169.80	7.13	5.60E-08	-0.13	5.57E-08	1.1	6.13E-08	1569.44	5.66E-08	0%	
11/02	1321	180	169.85	34.88	5.60E-08	0.00	5.57E-08	1.1	6.13E-08	1570.20	5.66E-08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-13 STAGE TWO
Geometric factor - G = 0.006243"
Depth factor = 356.8"
TC values from TEG-3

Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/02	1625	11040	172.92	19.50	5.75E-08	0.13	5.80E-08	1.1	6.38E-08	1619.69	5.67E-08	0%	
11/02	1630	300	173.00	35.44	5.75E-08	0.00	5.80E-08	1.1	6.38E-08	1621.00	5.67E-08	0%	Refill
11/03	758	55660	188.47	34.31	5.75E-08	0.00	5.80E-08	1.1	6.38E-08	1735.03	5.73E-08	1%	Dry refill
11/03	1114	11760	191.73	19.56	5.18E-08	0.00	5.18E-08	1.1	5.70E-08	1782.49	5.73E-08	0%	
11/03	1504	13800	195.57	3.38	5.05E-08	0.18	5.11E-08	1.1	5.62E-08	1834.55	5.73E-08	0%	
11/03	1507	180	195.62	35.31	5.05E-08	0.00	5.11E-08	1.1	5.62E-08	1835.22	5.73E-08	0%	Refill
11/04	808	61260	212.63	34.06	5.05E-08	0.00	5.11E-08	1.1	5.62E-08	1948.83	5.72E-08	0%	Dry refill
11/04	1218	14860	216.77	15.38	5.22E-08	0.00	5.22E-08	1.1	5.74E-08	2008.94	5.72E-08	0%	
11/04	1605	13740	220.58	35.25	5.22E-08	0.00	5.22E-08	1.1	5.74E-08	2058.43	5.72E-08	0%	Dry refill
11/05	755	57000	236.42	33.50	5.22E-08	0.00	5.22E-08	1.1	5.74E-08	2171.85	5.72E-08	0%	Dry refill
11/05	1333	20280	242.05	9.50	4.98E-08	-0.12	4.94E-08	1.1	5.43E-08	2249.07	5.71E-08	0%	
11/05	1335	120	242.08	35.75	4.98E-08	0.00	4.94E-08	1.1	5.43E-08	2249.52	5.71E-08	0%	Refill
11/05	1620	9900	244.83	23.63	5.02E-08	0.18	5.10E-08	1.1	5.61E-08	2288.52	5.71E-08	0%	
11/05	1622	120	244.87	35.81	5.02E-08	0.00	5.10E-08	1.1	5.61E-08	2288.99	5.71E-08	0%	Refill
11/06	800	56280	260.50	33.38	5.02E-08	0.00	5.10E-08	1.1	5.61E-08	2404.21	5.71E-08	0%	Dry refill
11/06	1406	21960	266.60	7.56	4.94E-08	-0.06	4.93E-08	1.1	5.43E-08	2487.29	5.70E-08	0%	
11/06	1407	60	266.62	35.25	4.94E-08	0.00	4.93E-08	1.1	5.42E-08	2487.51	5.70E-08	0%	Refill
11/06	1643	9360	269.22	23.63	5.10E-08	0.06	5.12E-08	1.1	5.64E-08	2524.90	5.70E-08	0%	
11/06	1644	60	269.23	35.88	5.10E-08	0.00	5.12E-08	1.1	5.63E-08	2525.14	5.70E-08	0%	Refill
11/07	828	56640	284.97	34.38	5.10E-08	0.00	5.12E-08	1.1	5.63E-08	2640.59	5.70E-08	0%	Dry refill
11/07	1400	19920	290.50	11.06	4.89E-08	-0.13	4.86E-08	1.1	5.35E-08	2715.62	5.69E-08	0%	
11/07	1401	60	290.52	35.75	4.89E-08	0.00	4.86E-08	1.1	5.35E-08	2715.85	5.69E-08	0%	Refill
11/07	1645	9840	293.25	23.69	5.03E-08	0.07	5.06E-08	1.1	5.56E-08	2754.65	5.69E-08	0%	
11/07	1647	120	293.28	36.00	5.03E-08	0.00	5.06E-08	1.1	5.57E-08	2755.12	5.69E-08	0%	Refill
11/08	830	56580	309.00	33.63	5.03E-08	0.00	5.06E-08	1.1	5.57E-08	2870.95	5.68E-08	0%	Dry refill
11/08	1318	17280	313.80	12.75	5.04E-08	-0.19	5.00E-08	1.1	5.50E-08	2938.14	5.68E-08	0%	
11/08	1319	60	313.82	35.75	5.04E-08	0.00	5.00E-08	1.1	5.50E-08	2938.37	5.68E-08	0%	Refill
11/08	1602	9680	316.51	24.13	4.92E-08	-0.19	4.84E-08	1.1	5.32E-08	2975.76	5.68E-08	0%	
11/08	1603	60	316.52	35.88	4.92E-08	0.00	4.84E-08	1.1	5.32E-08	2975.99	5.68E-08	0%	Refill
11/09	718	54900	331.77	33.44	4.92E-08	0.00	4.84E-08	1.1	5.32E-08	3091.44	5.66E-08	0%	Dry refill
11/09	1337	22740	338.09	7.50	4.80E-08	-0.12	4.77E-08	1.1	5.25E-08	3174.90	5.65E-08	0%	
11/09	1338	60	338.11	35.75	4.80E-08	0.00	4.77E-08	1.1	5.25E-08	3175.12	5.65E-08	0%	Refill

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE TWO DATA

TSB-13 STAGE TWO
Geometric factor – G = 0.006243"
Depth factor = 356.6"
TC values from TEG-3

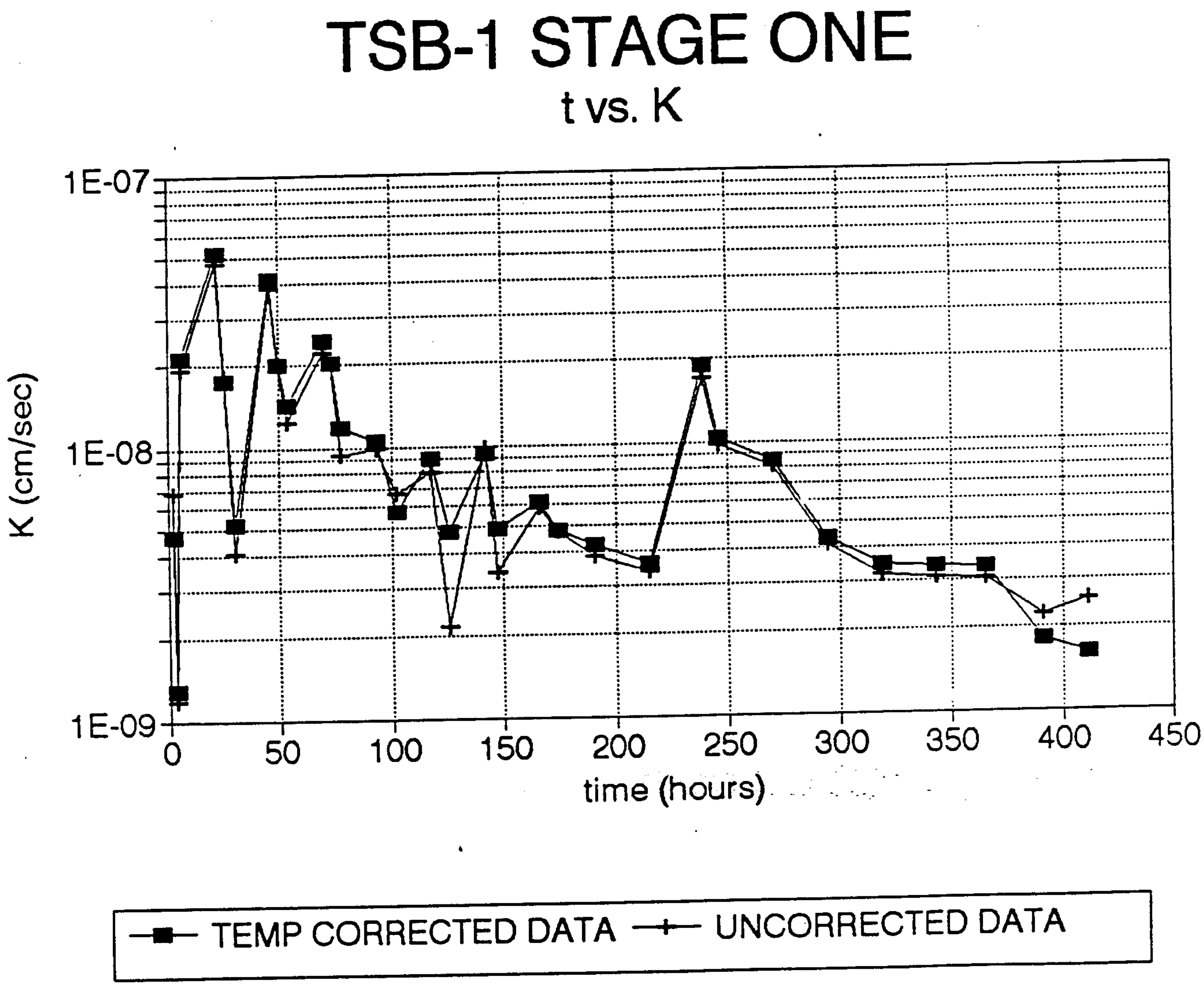
Date	Time	elapsed time seconds	cumulative elapsed time hours	Rt	K1	TC	K1C	visc. factor	K1CT	cumulative volume (cc)	K (twa)	RPD (K1wa)	Comments
11/09	1619	9660	340.79	24.13	4.93E-06	0.00	4.93E-06	1.1	5.43E-06	3212.51	5.65E-06	0%	
11/09	1620	60	340.81	36.00	4.93E-06	0.00	4.93E-06	1.1	5.42E-06	3212.74	5.65E-06	0%	Refill
11/10	725	54300	355.89	34.25	4.93E-06	0.00	4.93E-06	1.1	5.42E-06	3326.57	5.64E-06	0%	Dry refill
11/10	1341	22560	362.16	9.00	4.69E-06	-0.13	4.67E-06	1.1	5.13E-06	3409.62	5.63E-06	0%	
11/10	1342	60	362.17	35.66	4.69E-06	0.00	4.67E-06	1.1	5.14E-06	3410.03	5.63E-06	0%	Refill
11/10	1620	9480	364.81	25.13	4.64E-06	0.00	4.64E-06	1.1	5.11E-06	3444.62	5.63E-06	0%	
11/10	1621	60	364.82	35.75	4.64E-06	0.00	4.64E-06	1.1	5.10E-06	3444.64	5.63E-06	0%	Refill
11/11	730	54540	379.97	34.66	4.64E-06	0.00	4.64E-06	1.1	5.10E-06	3559.67	5.61E-06	0%	Dry refill
11/11	1340	22200	386.14	10.56	4.58E-06	0.06	4.59E-06	1.1	5.05E-06	3636.12	5.60E-06	0%	END TEST

END OF TEST TSB-13 STAGE TWO

ATTACHMENT 3A

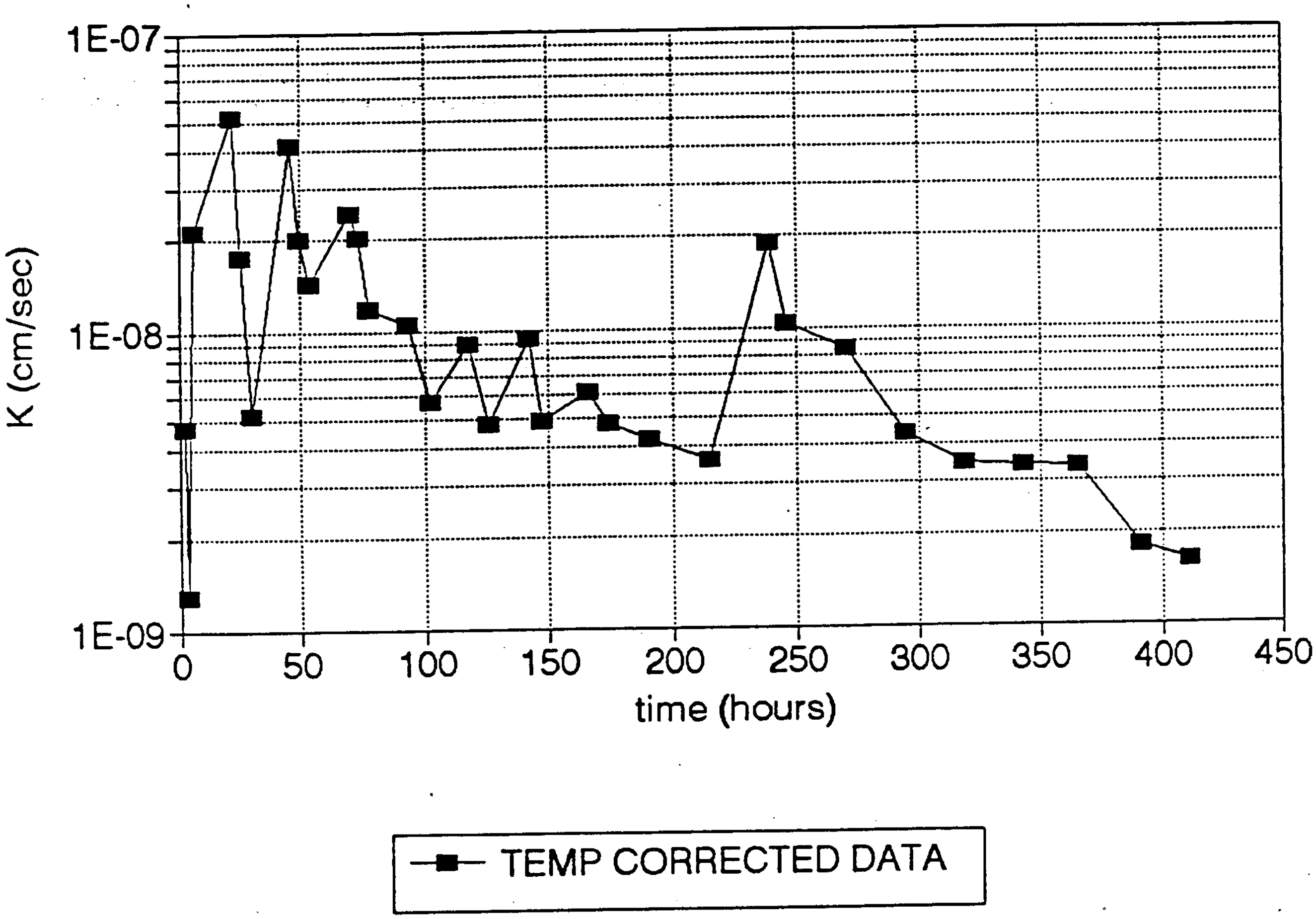
TSB DATA PLOTS

STAGE 1


TSB-1 STAGE ONE
t vs. K
1E-07
1E-08
1E-09
K (cm/sec)
0
50
100
150
200
250
300
350
400
450
time (hours)
TEMP CORRECTED DATA
UNCORRECTED DATA

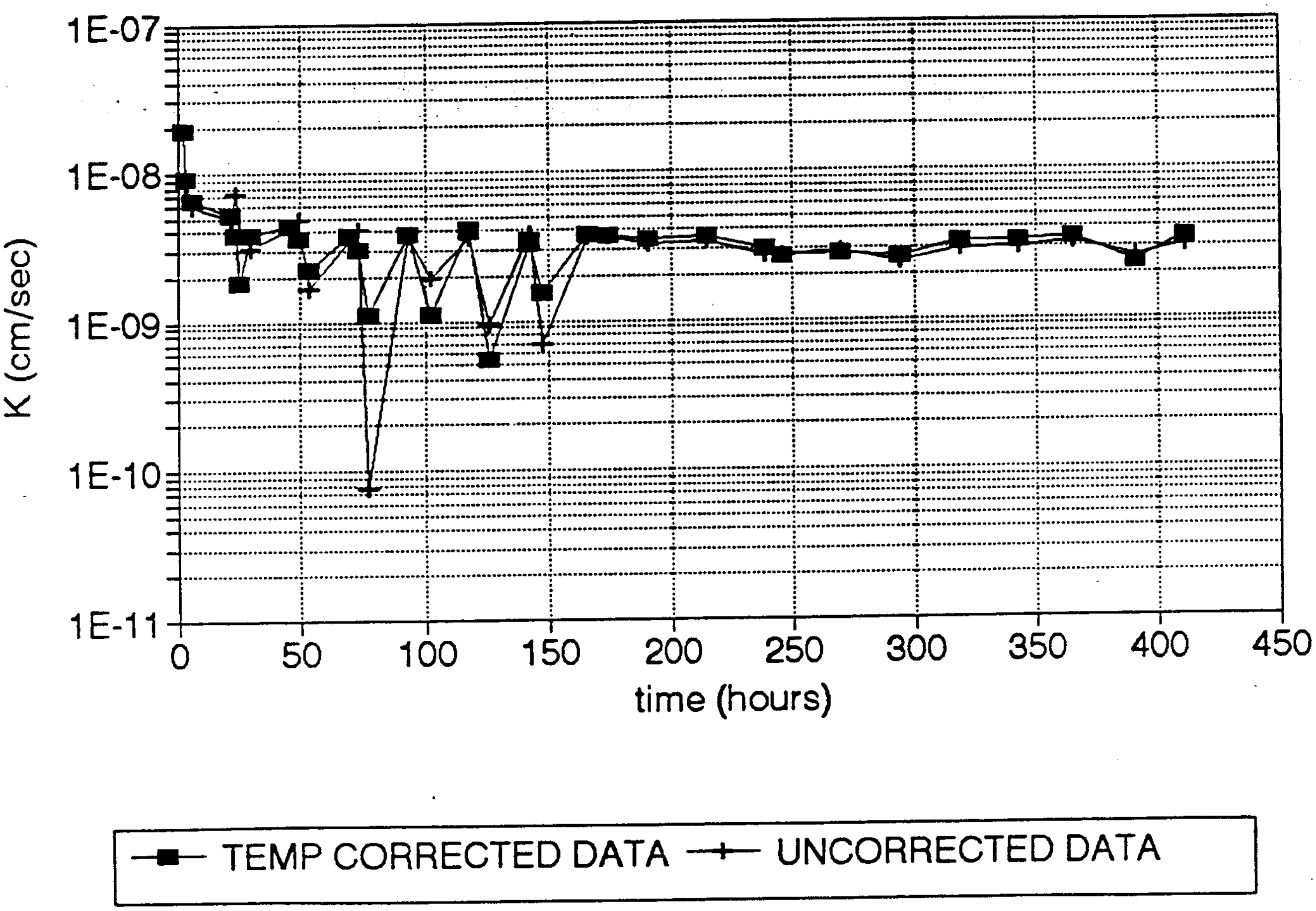
TSB-1 STAGE ONE

t vs. K



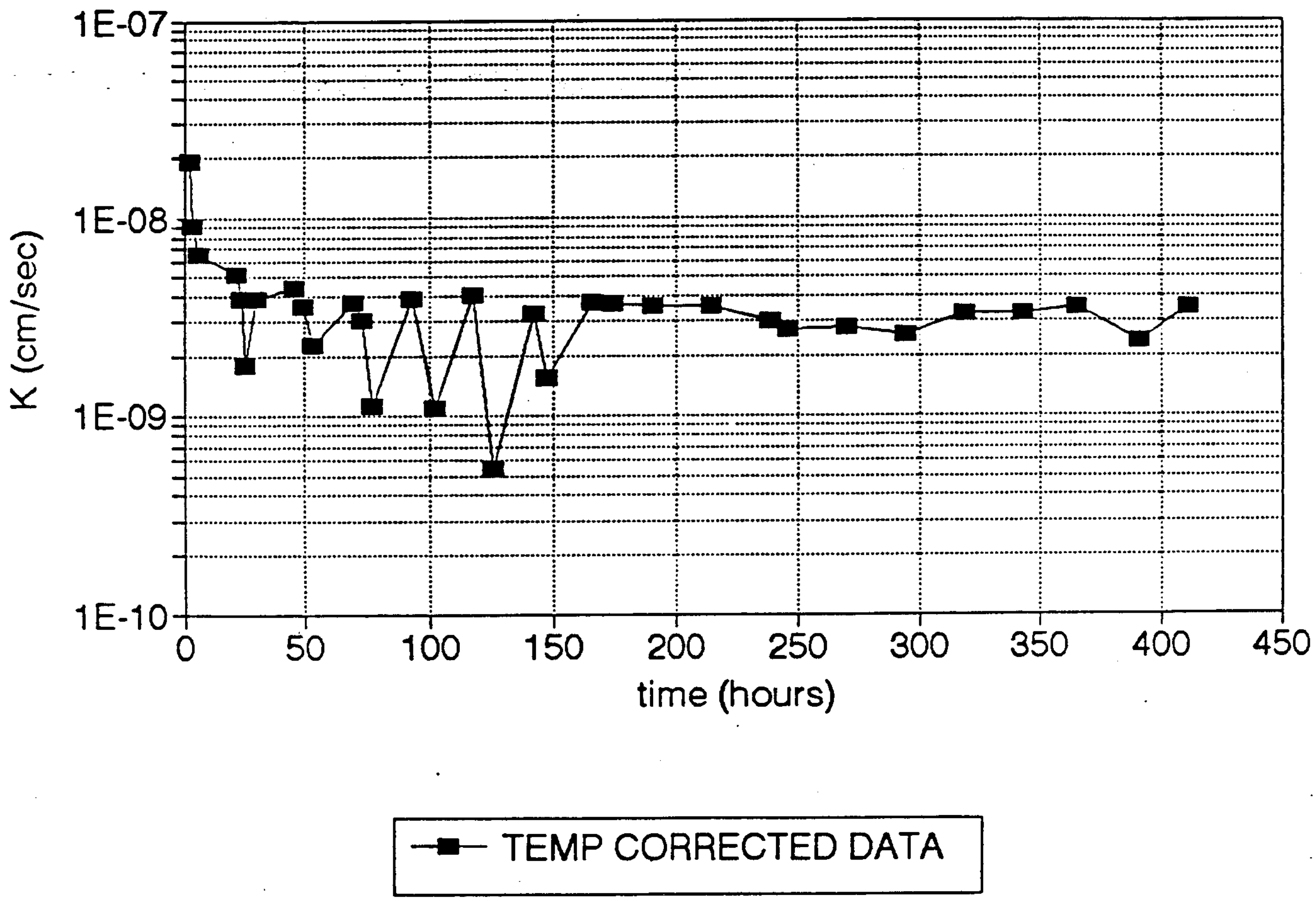
TSB-2 STAGE ONE

t vs. K



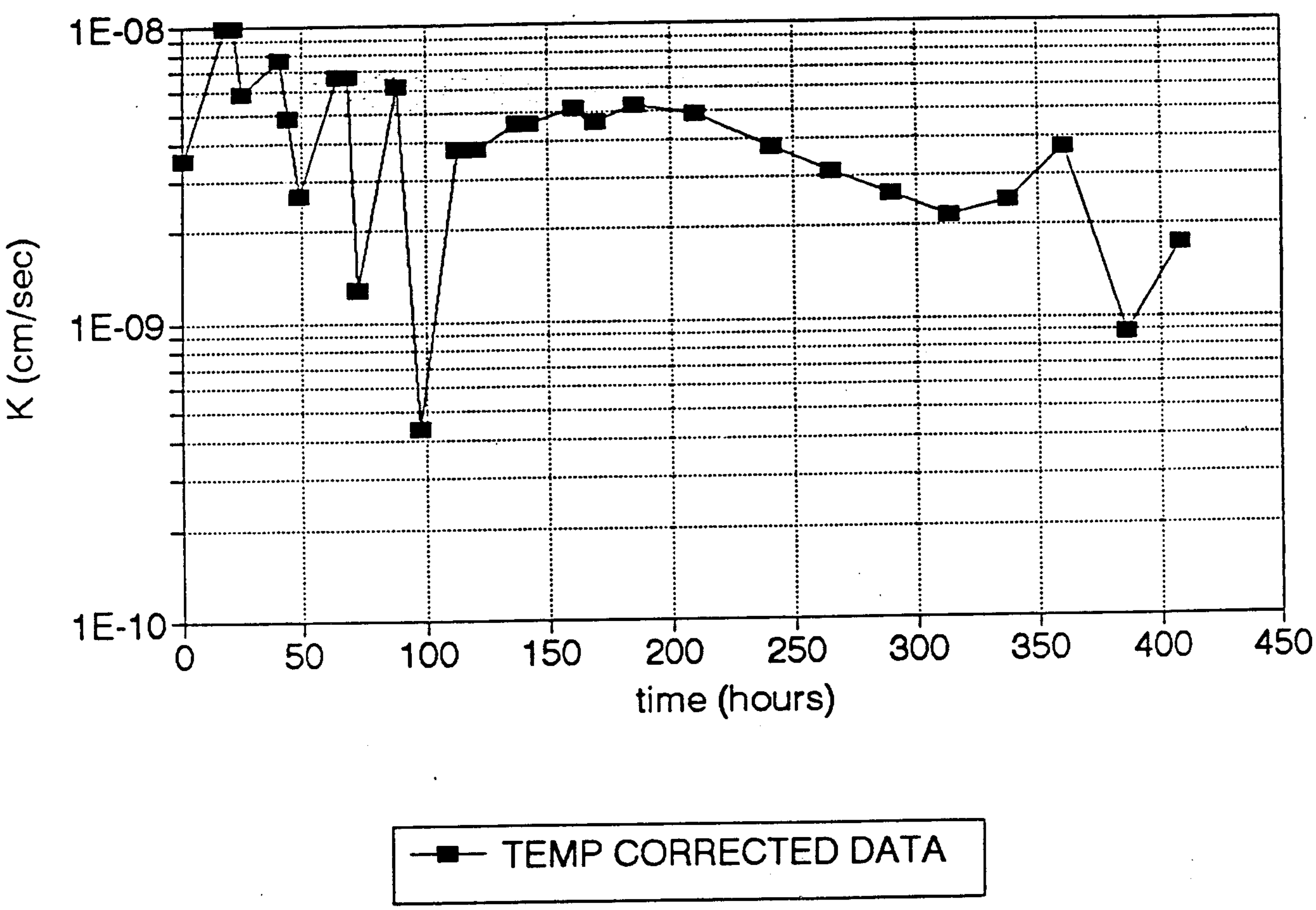
TSB-2 STAGE ONE

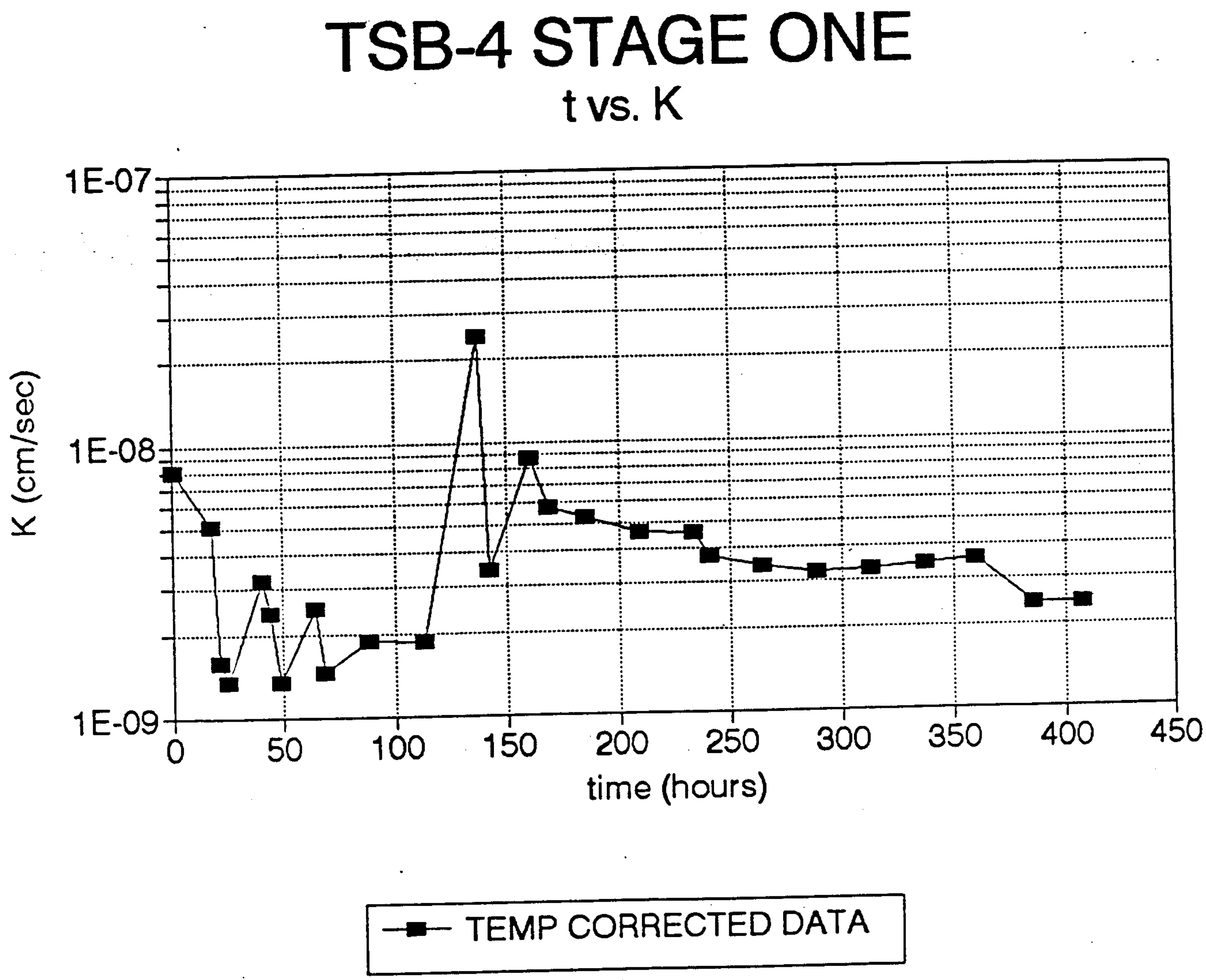
t vs. K



TSB-3 STAGE ONE

t vs. K

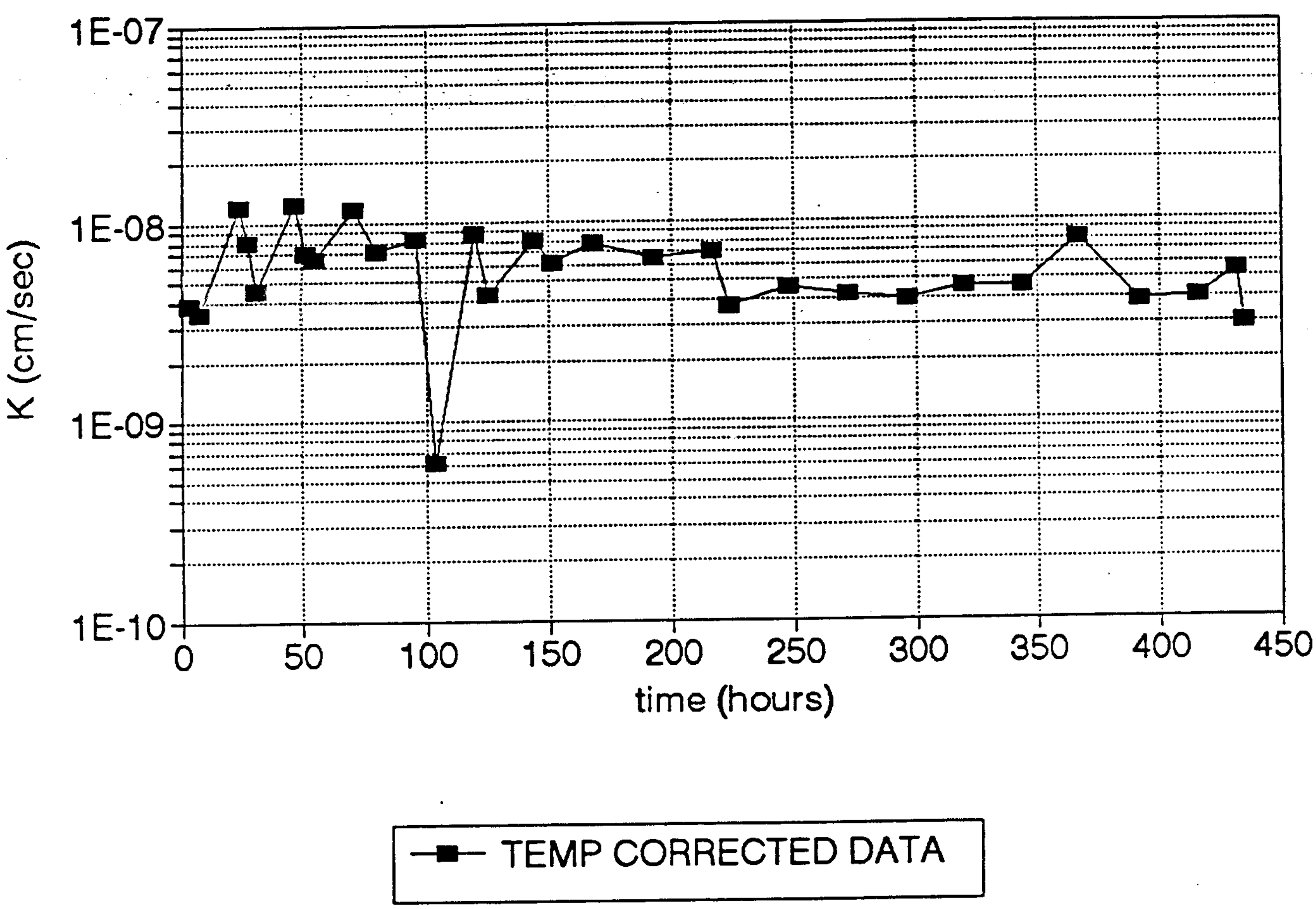




TSB-4 STAGE ONE
t vs. K
1E-07
1E-08
1E-09
K (cm/sec)
0
50
100
150
200
250
300
350
400
450
time (hours)
TEMP CORRECTED DATA

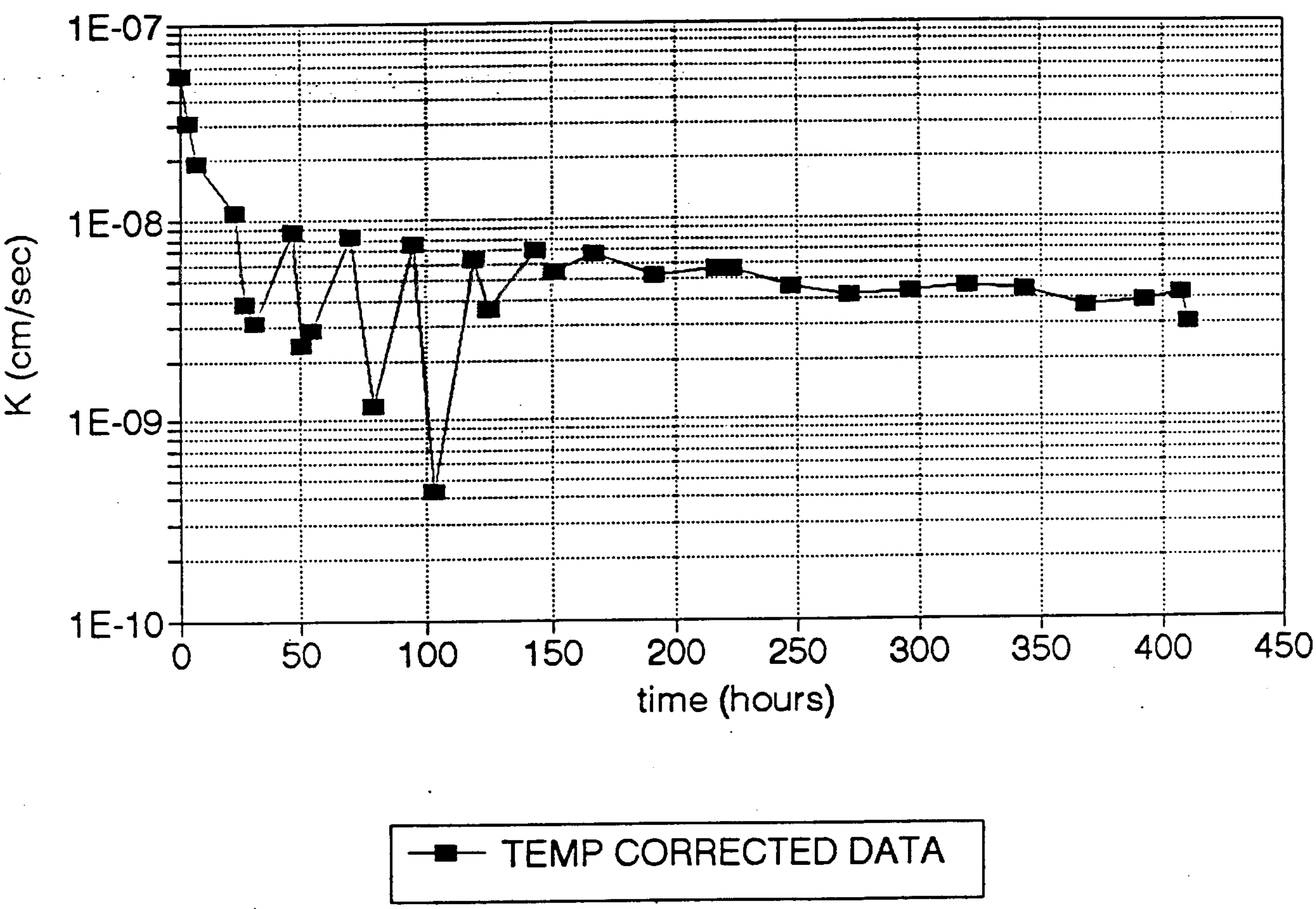
TSB-5 STAGE ONE

t vs. K



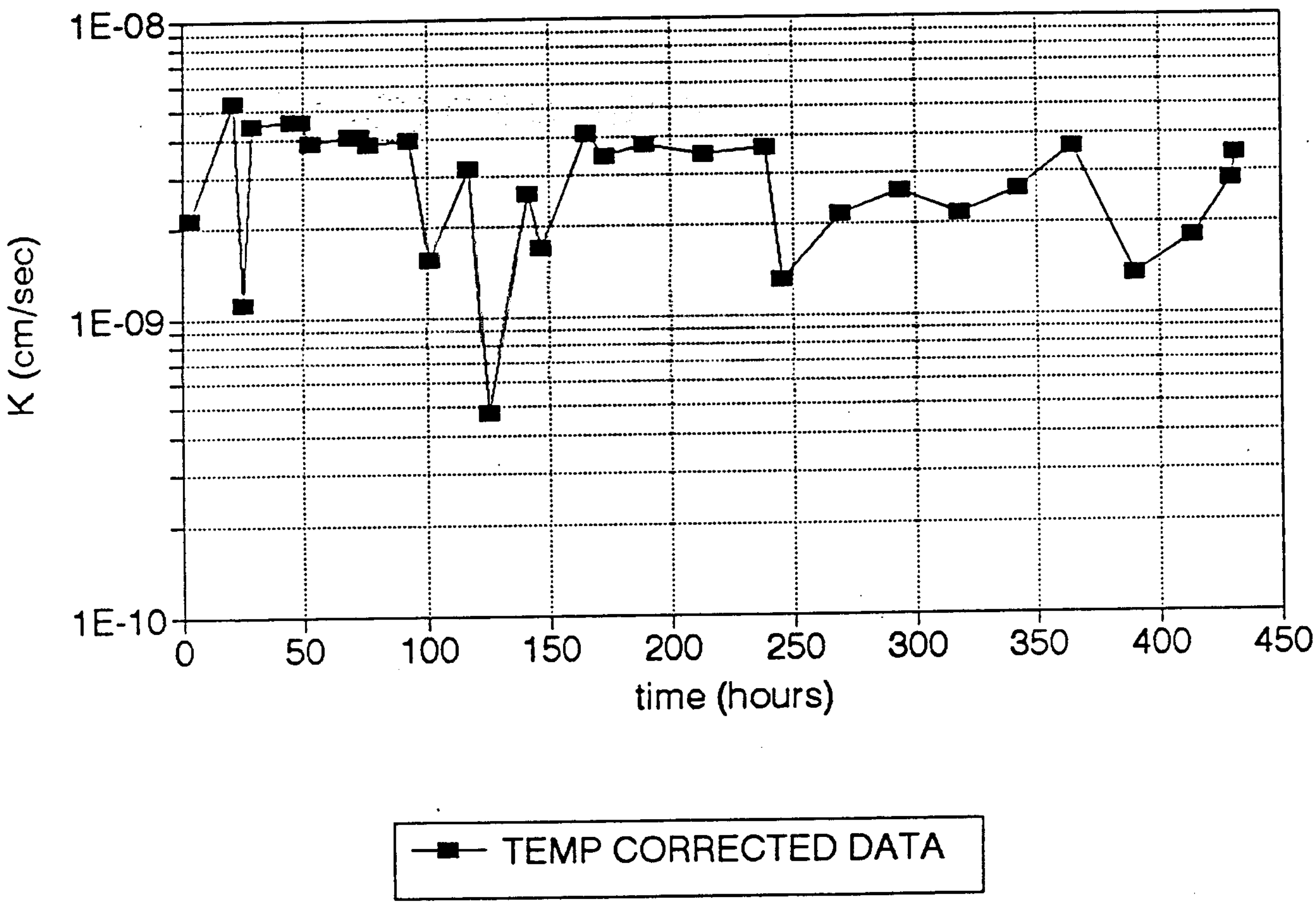
TSB-6 STAGE ONE

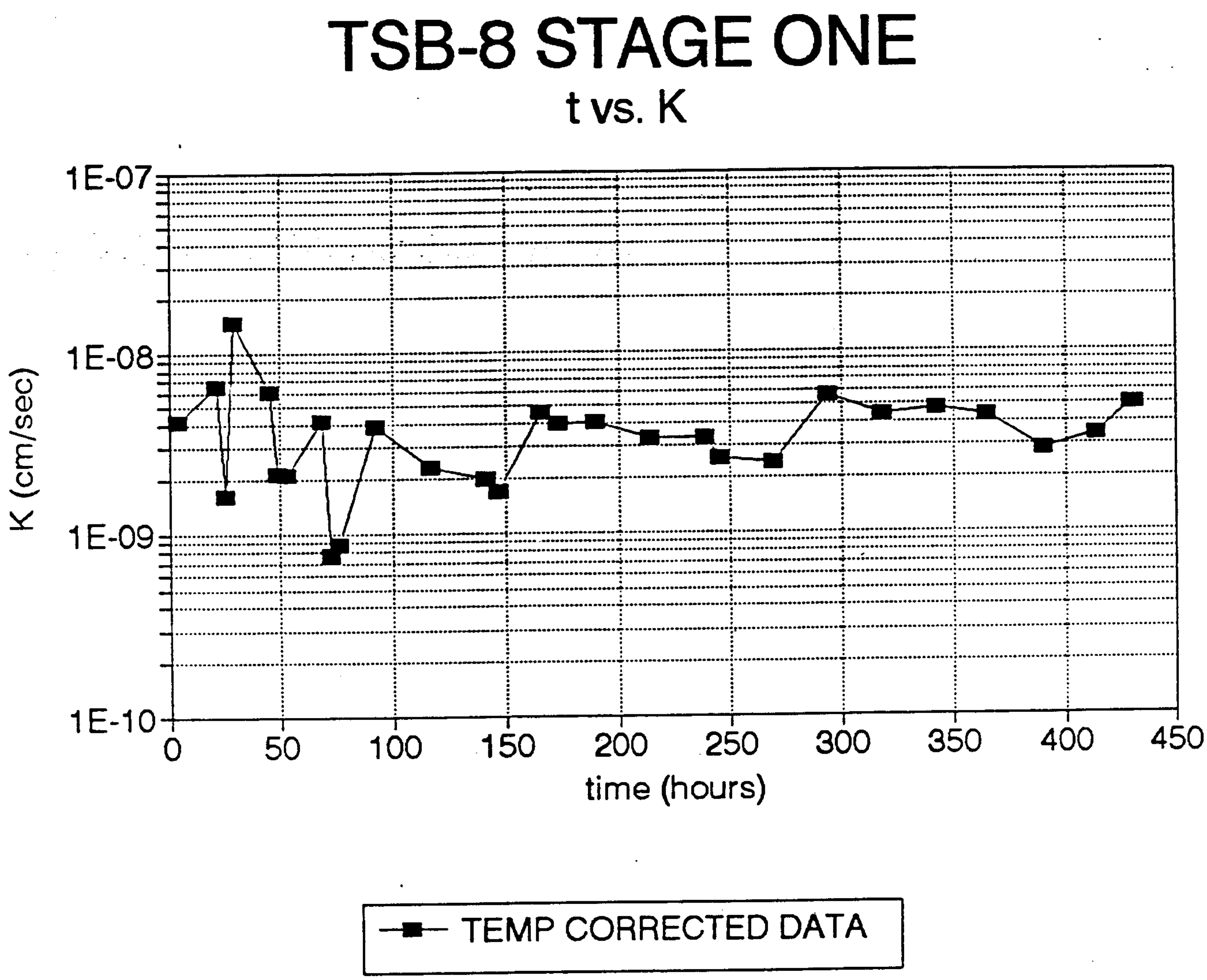
t vs. K



TSB-7 STAGE ONE

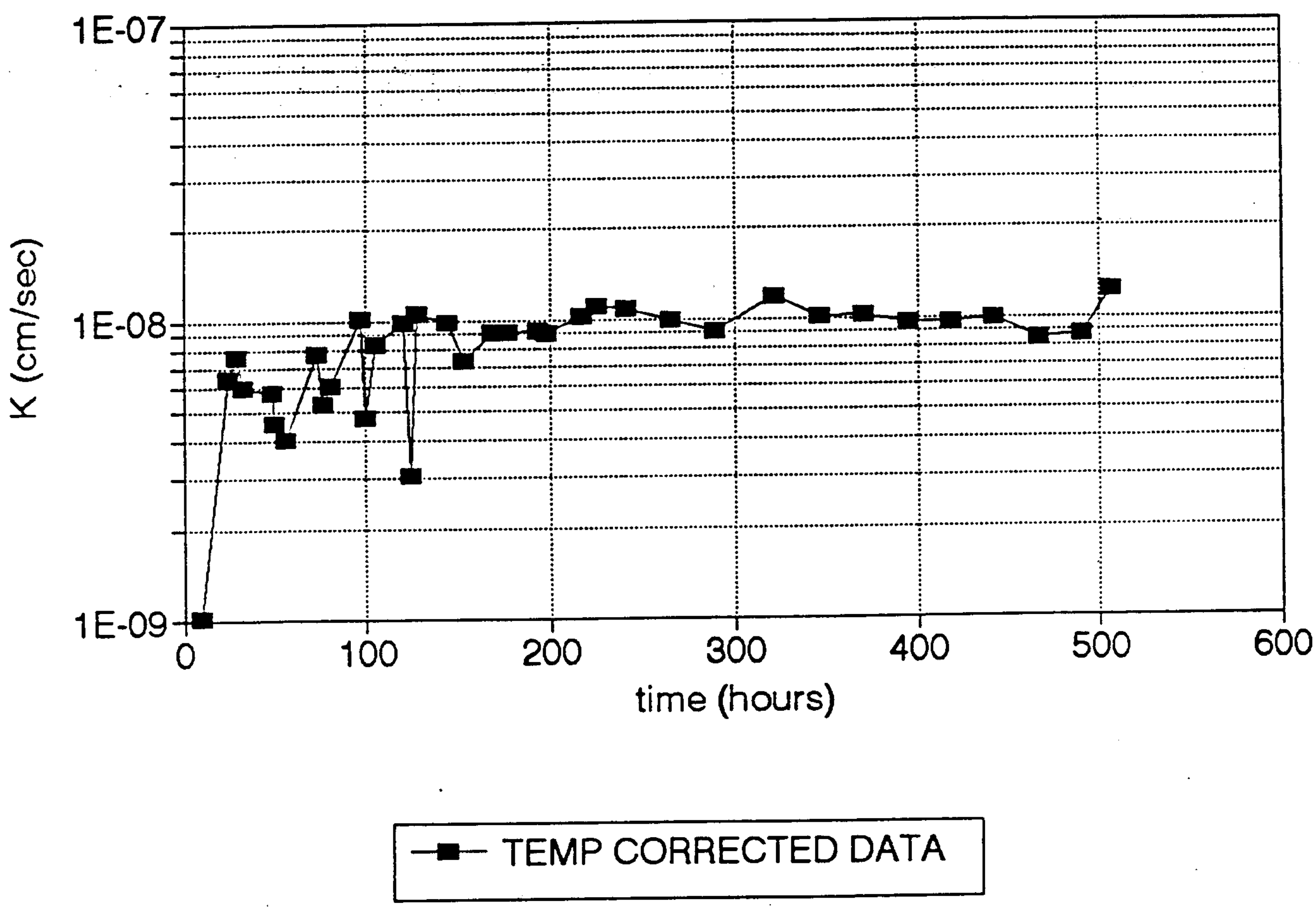
t vs. K



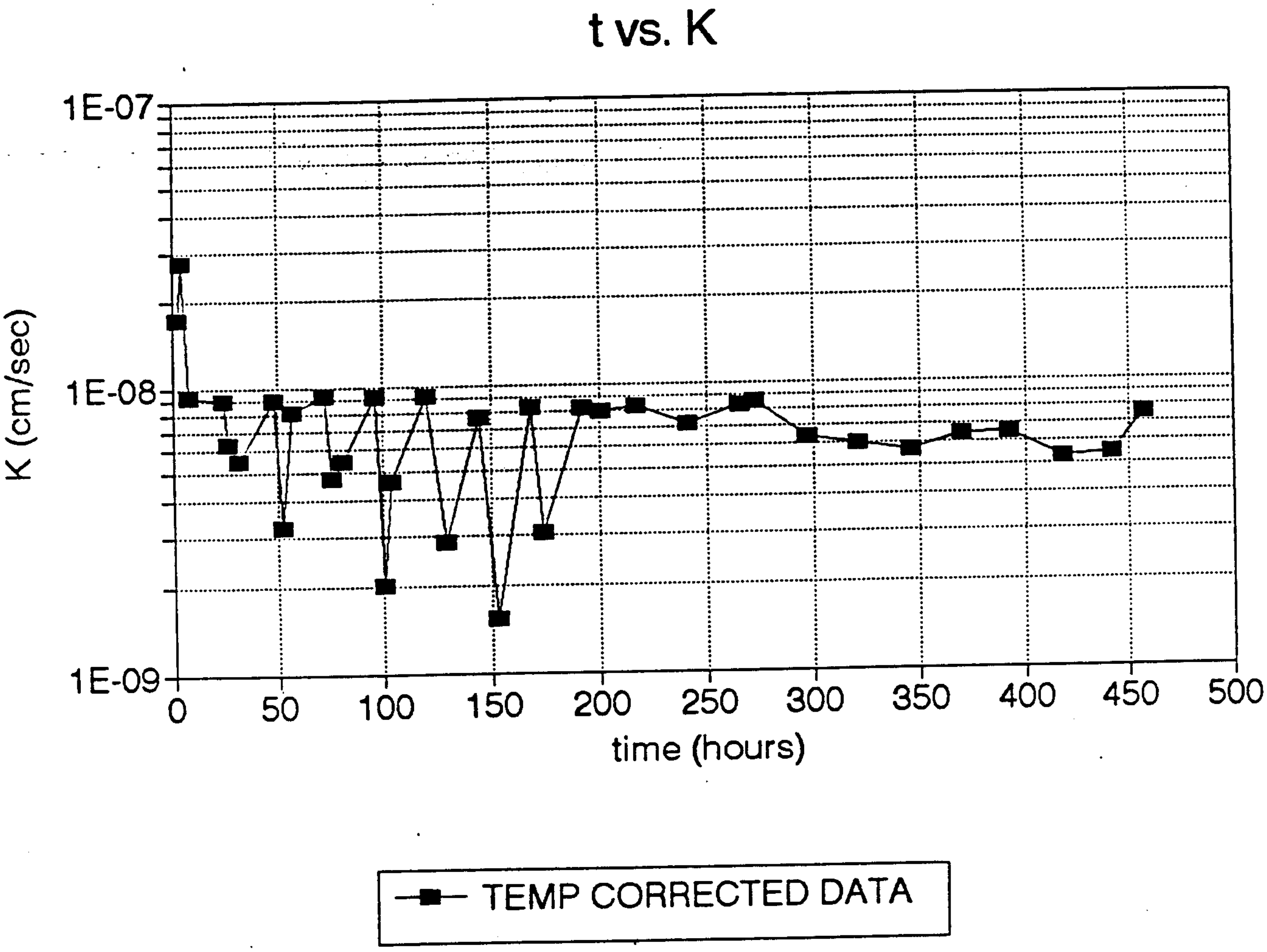

TSB-8 STAGE ONE
t vs. K
K (cm/sec)
1E-07
1E-08
1E-09
1E-10
0
50
100
150
200
250
300
350
400
450
time (hours)
TEMP CORRECTED DATA

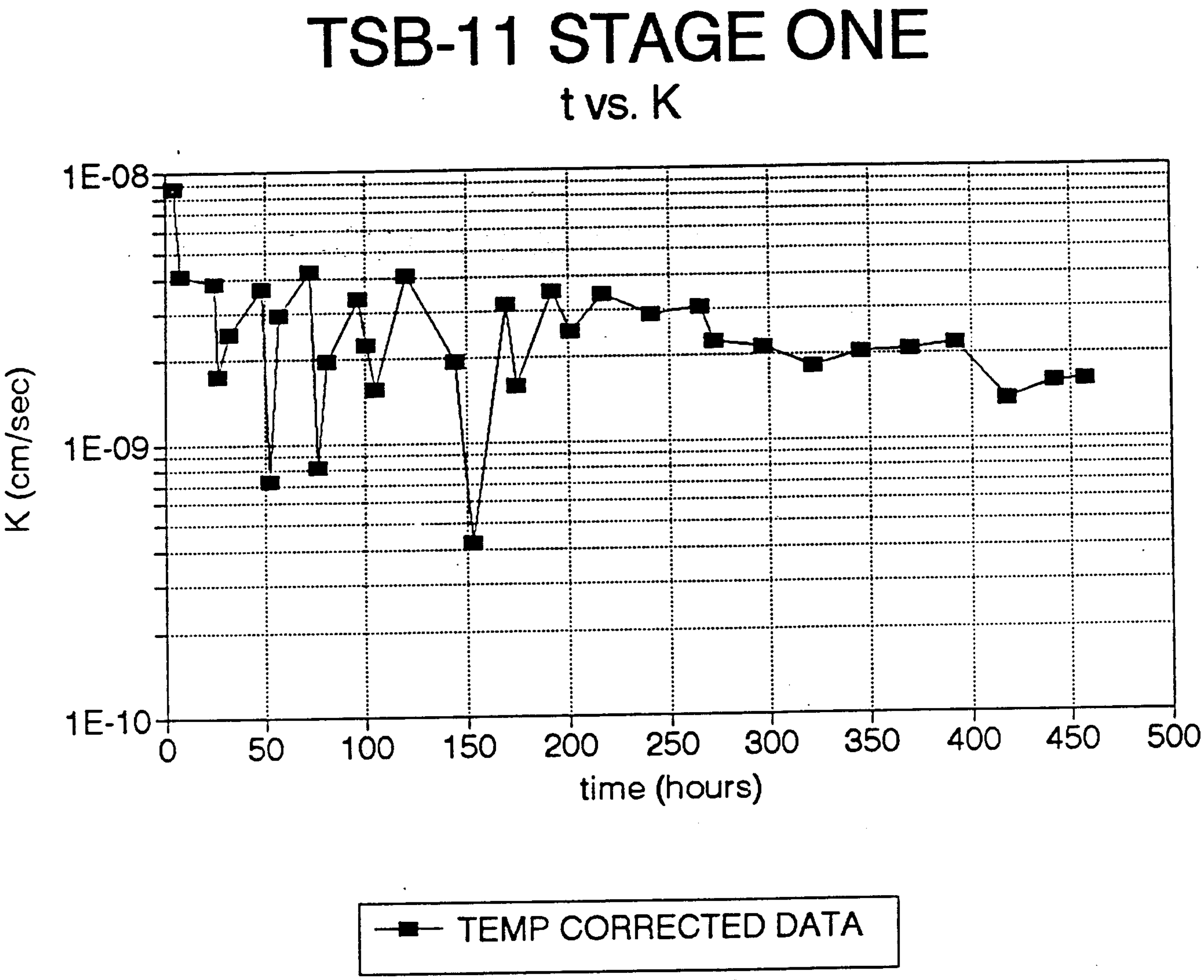
TSB-9 STAGE ONE

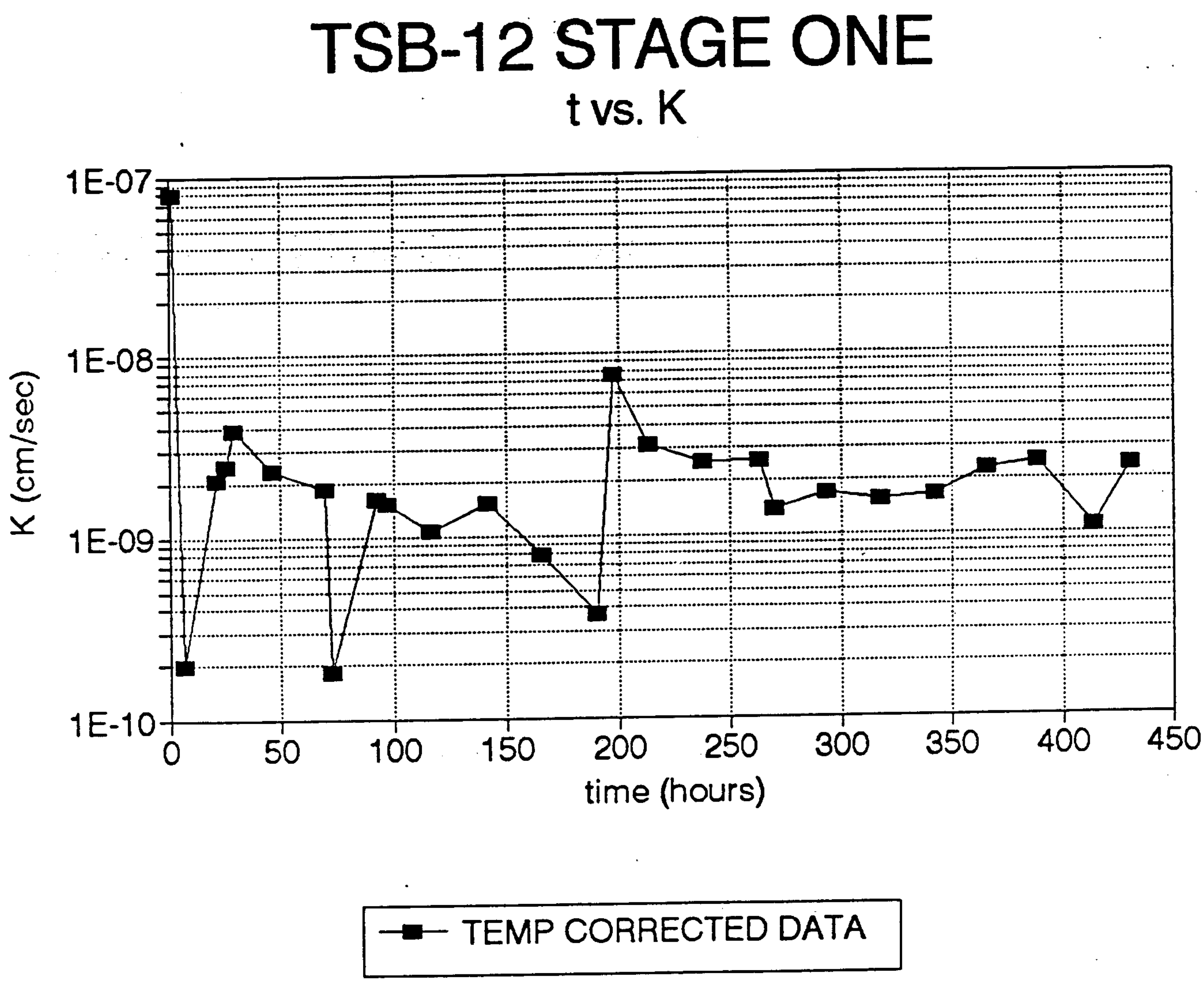
t vs. K



TSB-10 STAGE ONE



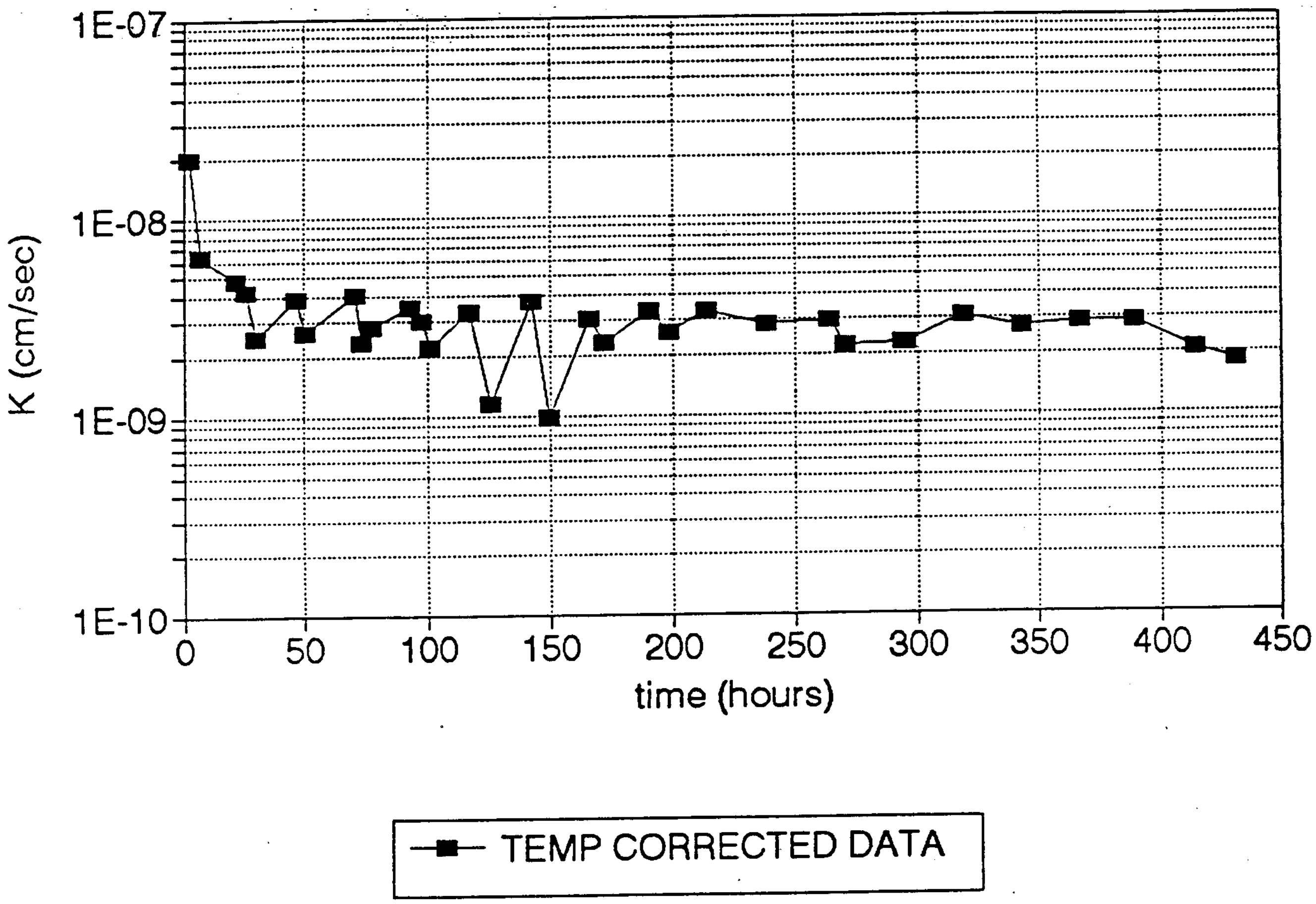

TSB-11 STAGE ONE
t vs. K
1E-08
1E-09
1E-10
K (cm/sec)
0
50
100
150
200
250
300
350
400
450
500
time (hours)
TEMP CORRECTED DATA



TSB-12 STAGE ONE
t vs. K
1E-07
1E-08
1E-09
1E-10
K (cm/sec)
0
50
100
150
200
250
300
350
400
450
time (hours)
TEMP CORRECTED DATA

TSB-13 STAGE ONE

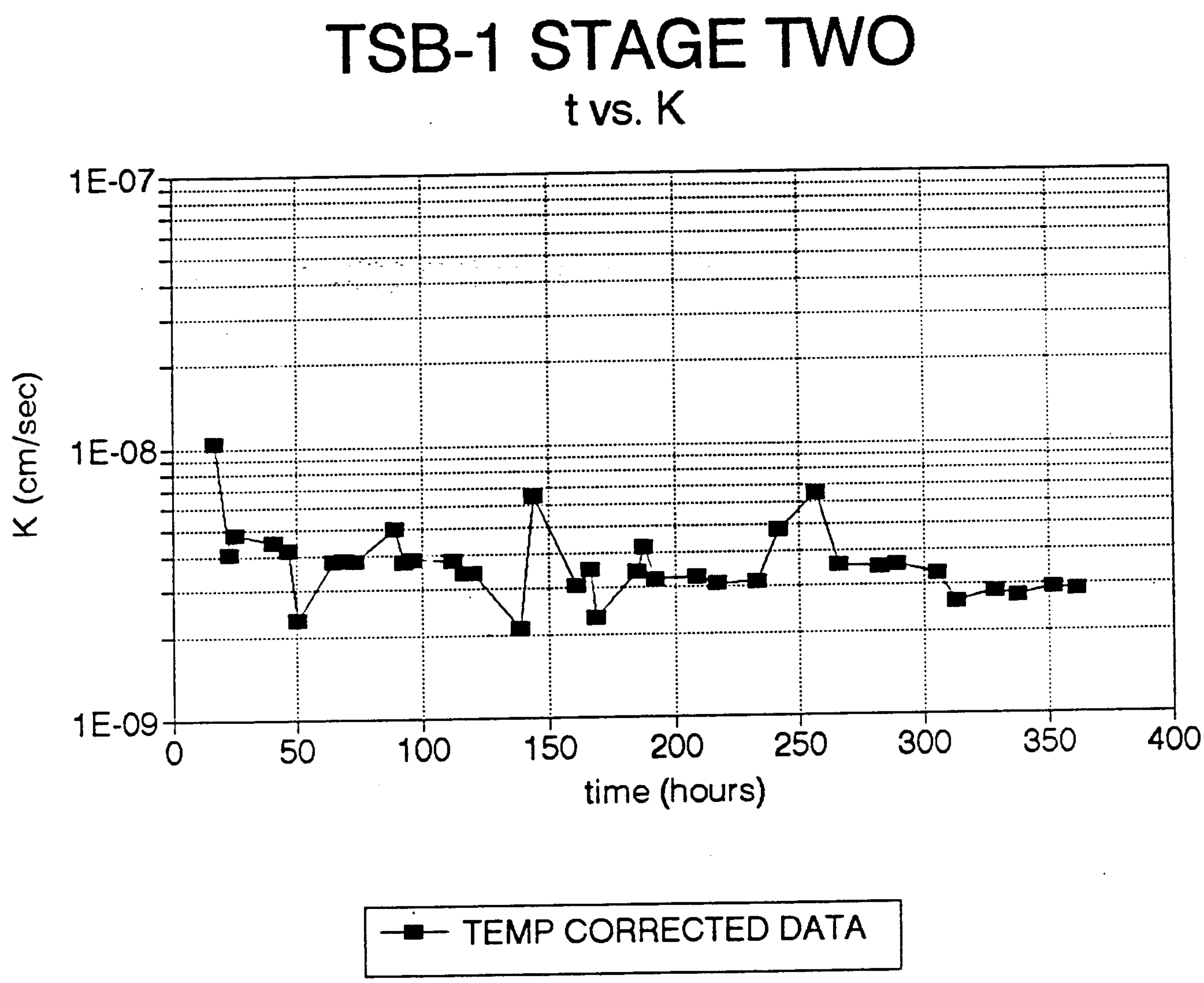
t vs. K



ATTACHMENT 3B

TSB DATA PLOTS

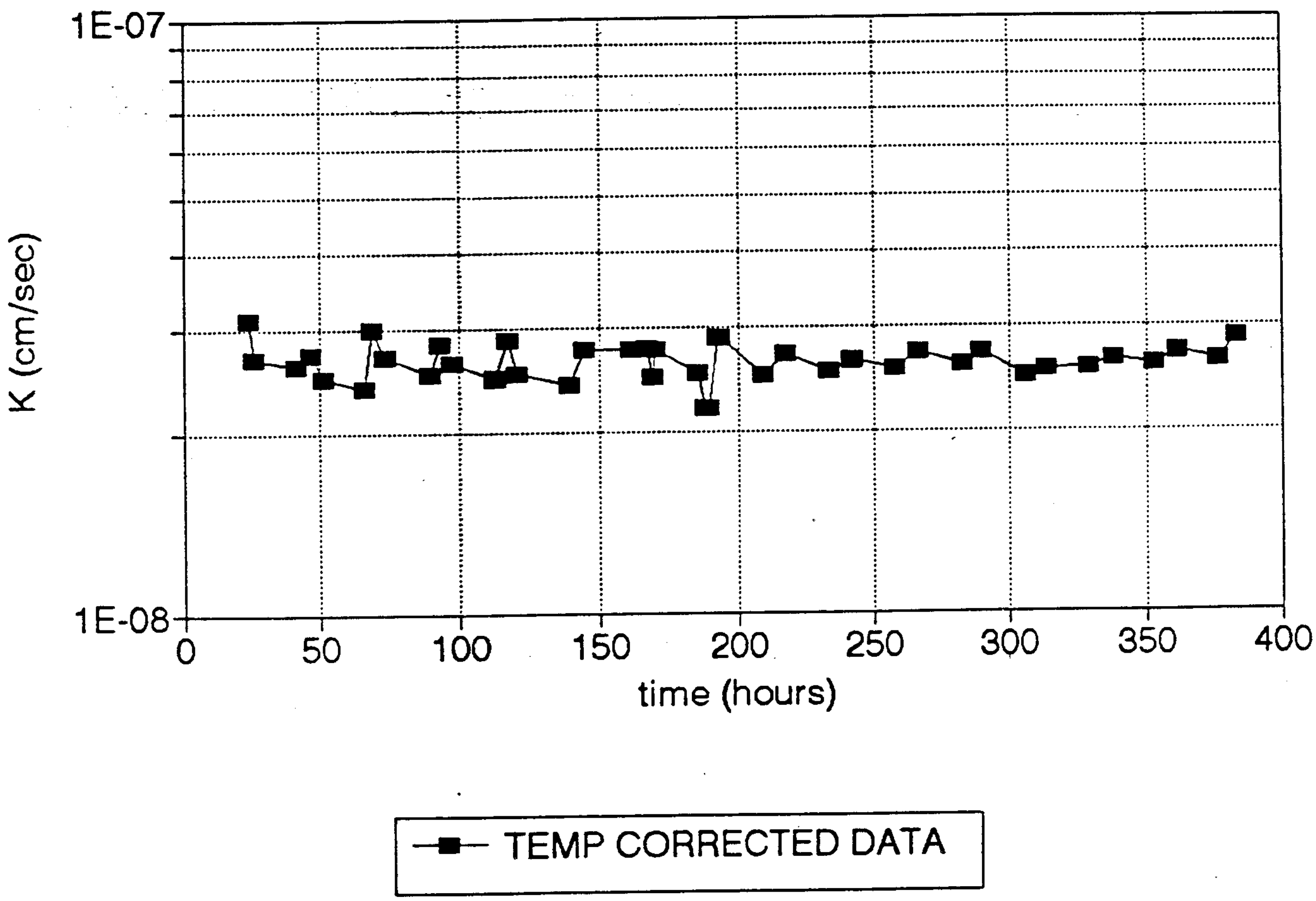
STAGE 2

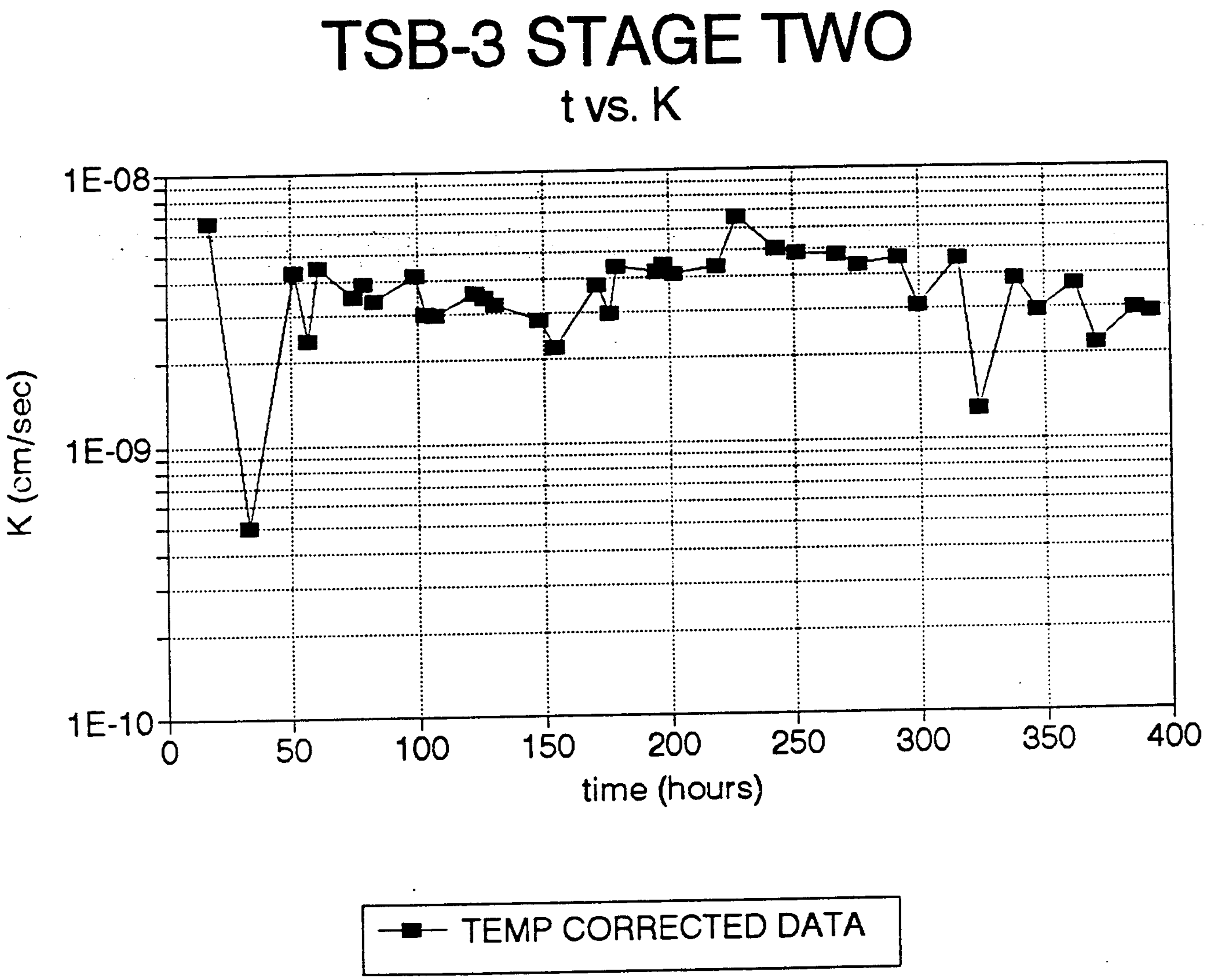


TSB-1 STAGE TWO
t vs. K
K (cm/sec)
1E-07
1E-08
1E-09
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

TSB-2 STAGE TWO

t vs. K

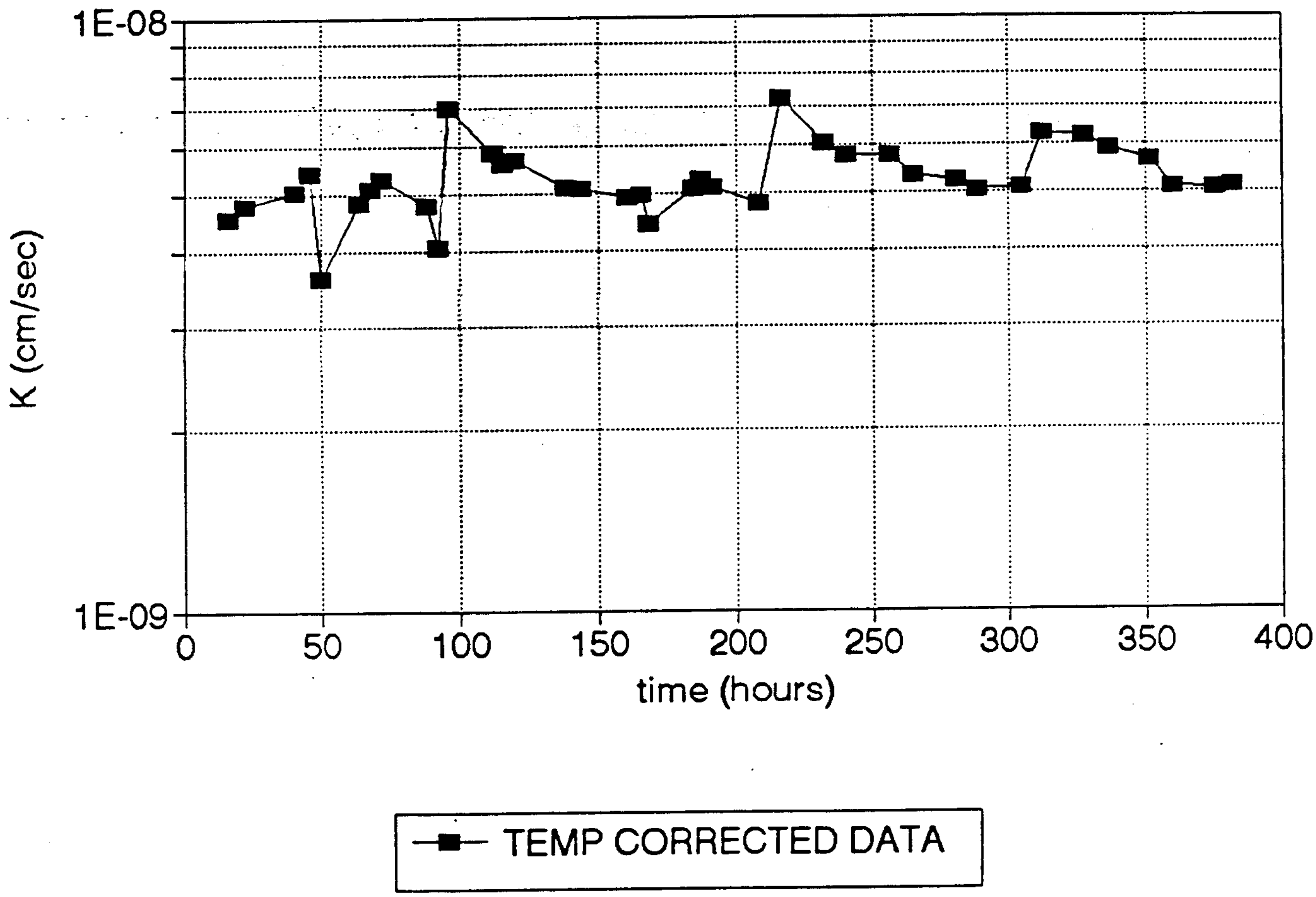


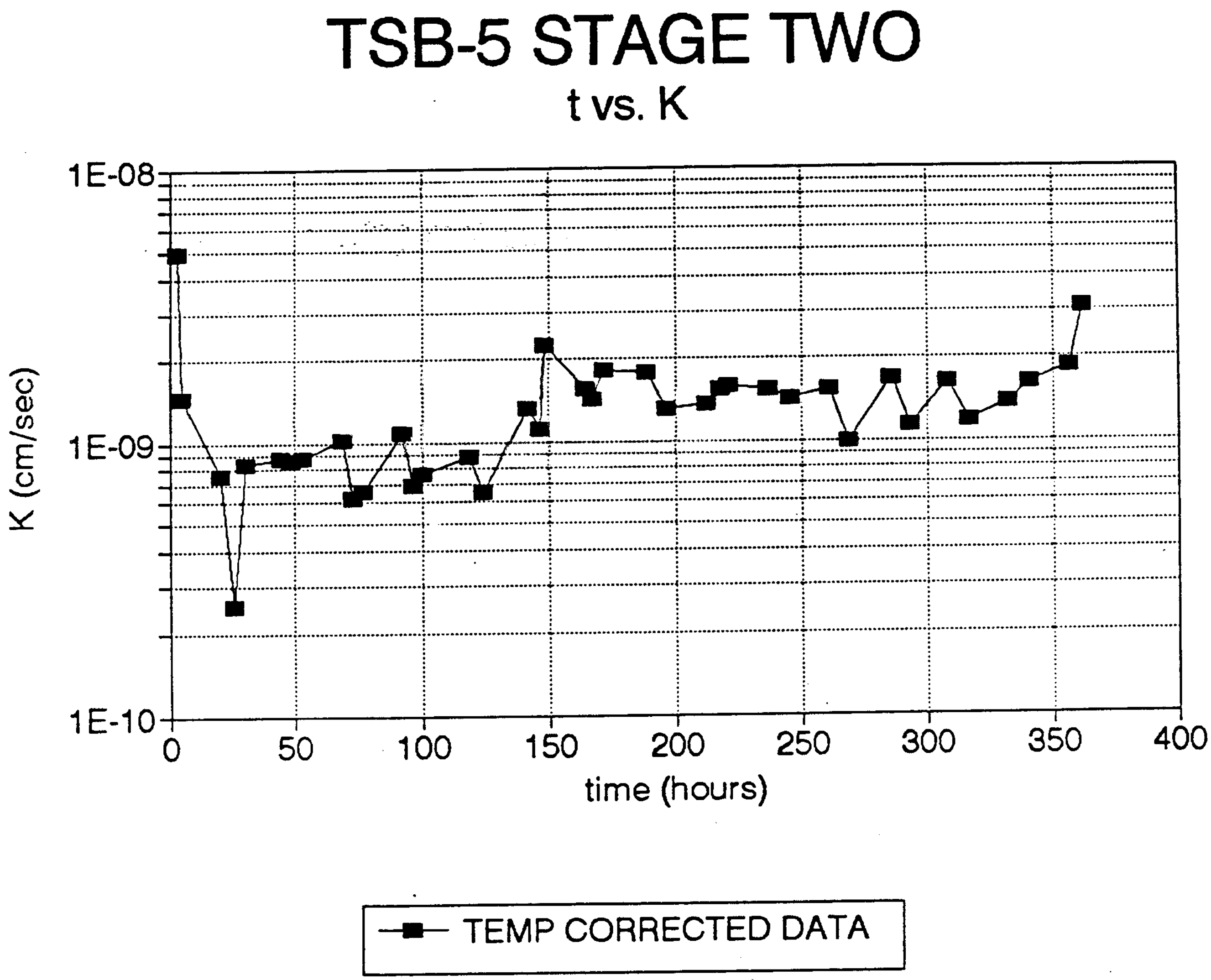


TSB-3 STAGE TWO
t vs. K
1E-08
1E-09
1E-10
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

TSB-4 STAGE TWO

t vs. K

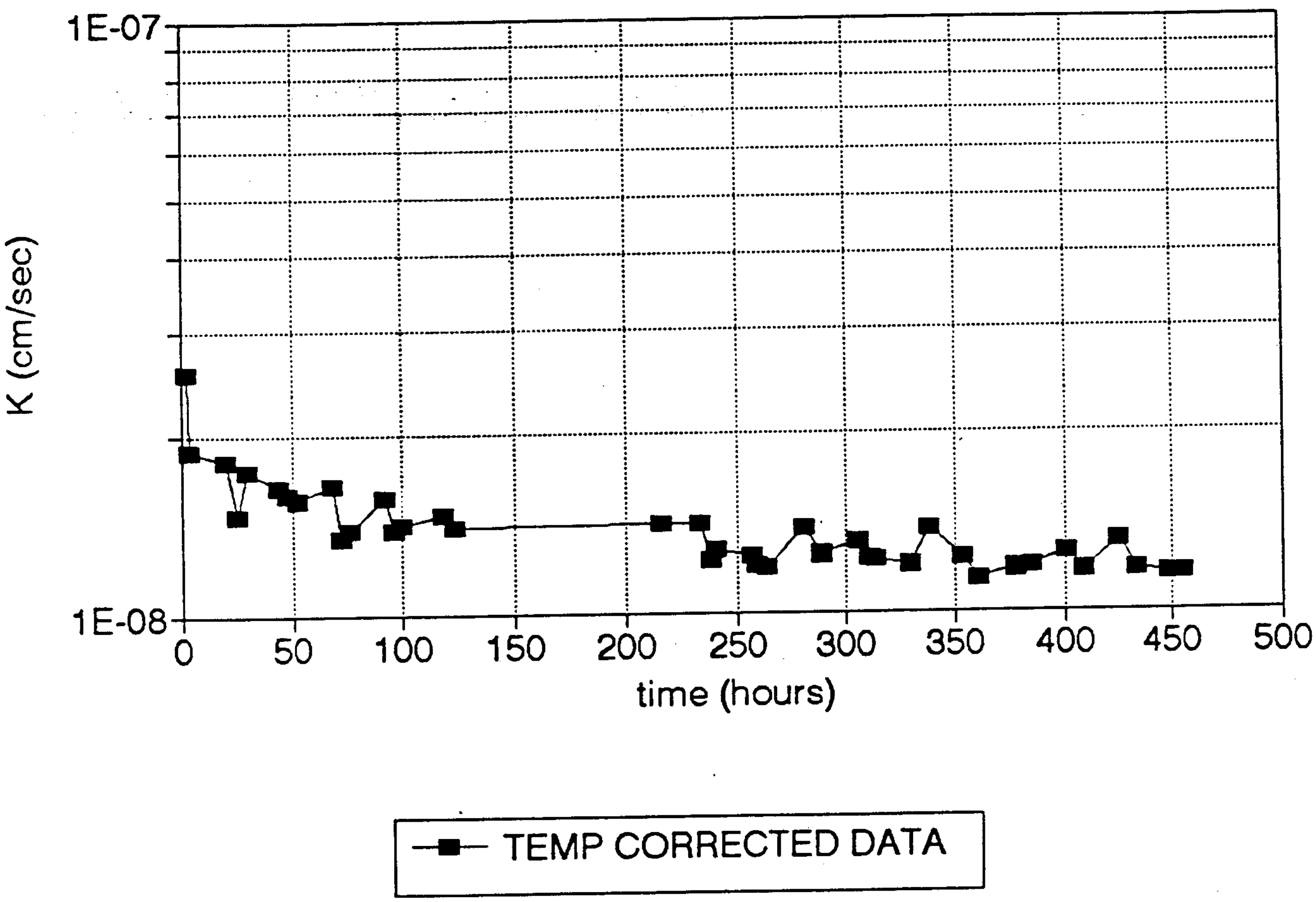


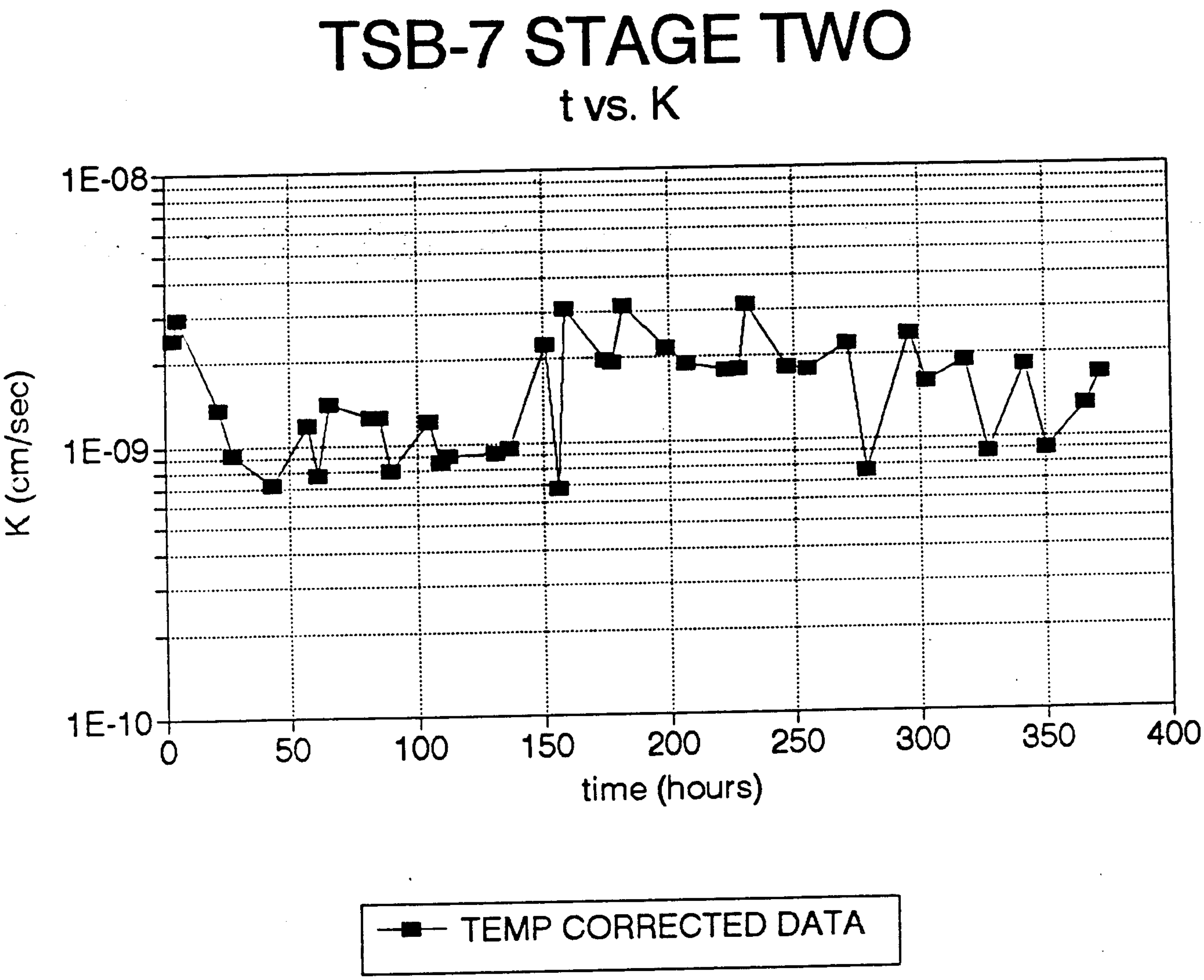


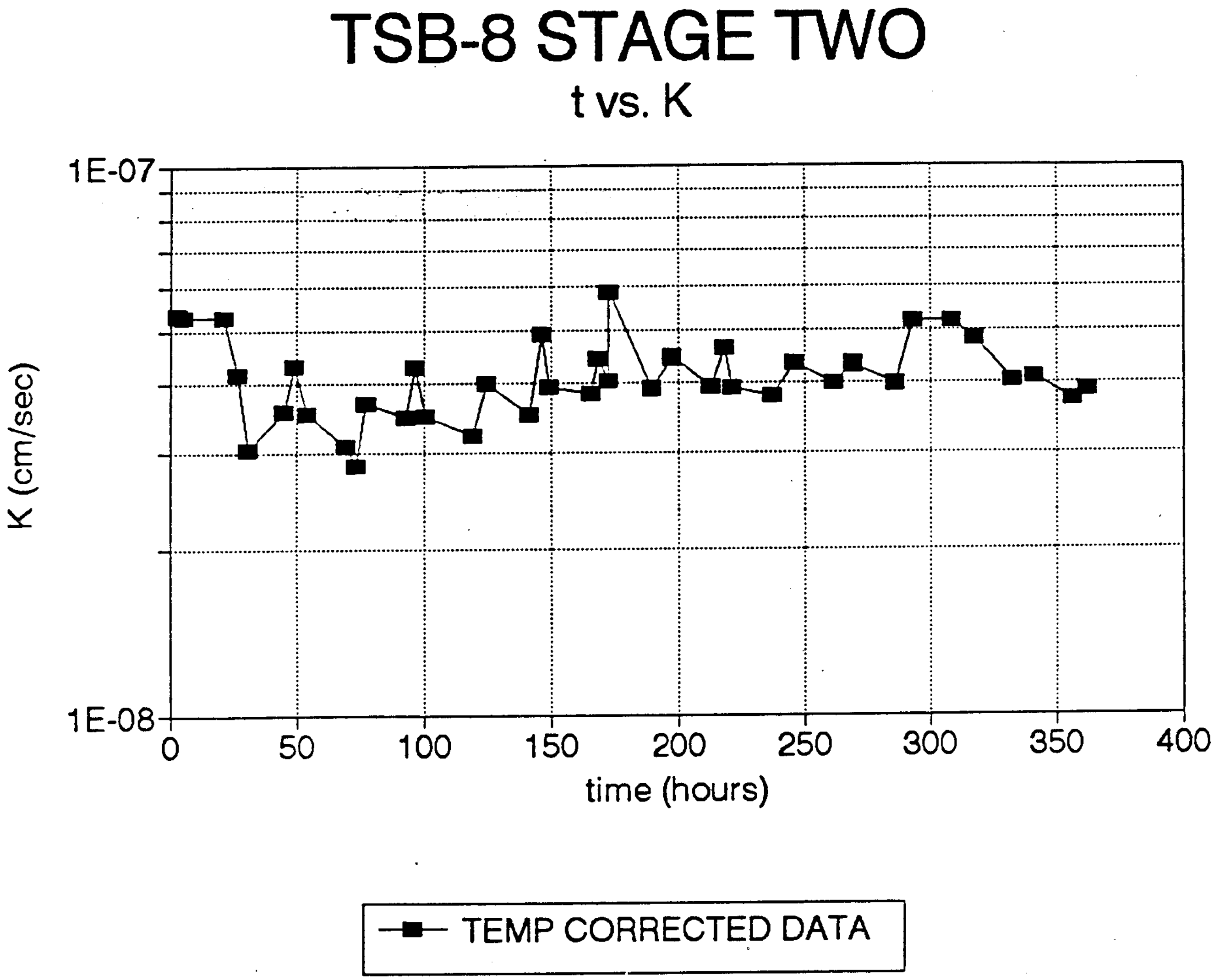
TSB-5 STAGE TWO
t vs. K
1E-08
1E-09
1E-10
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

TSB-6 STAGE TWO

t vs. K

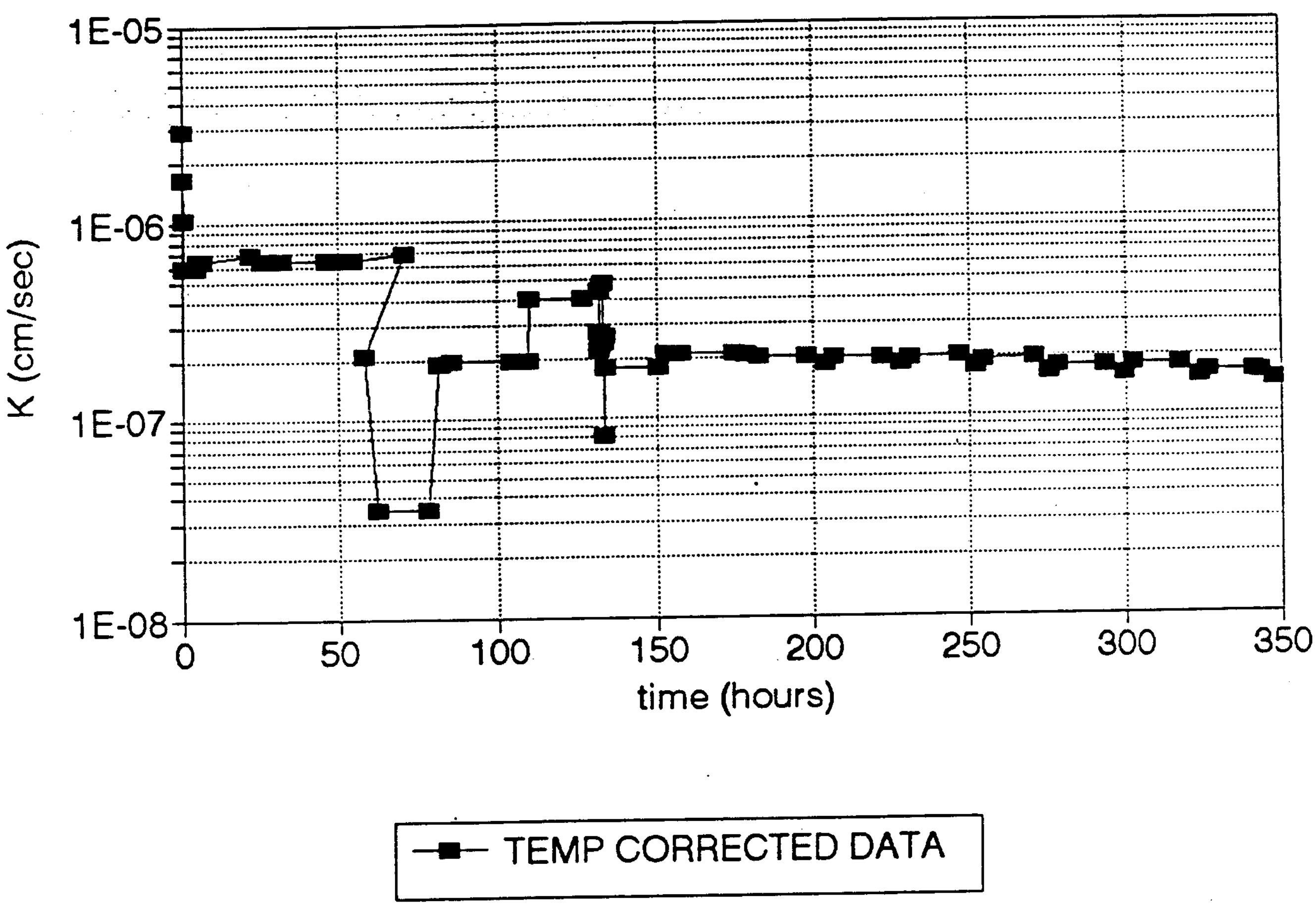


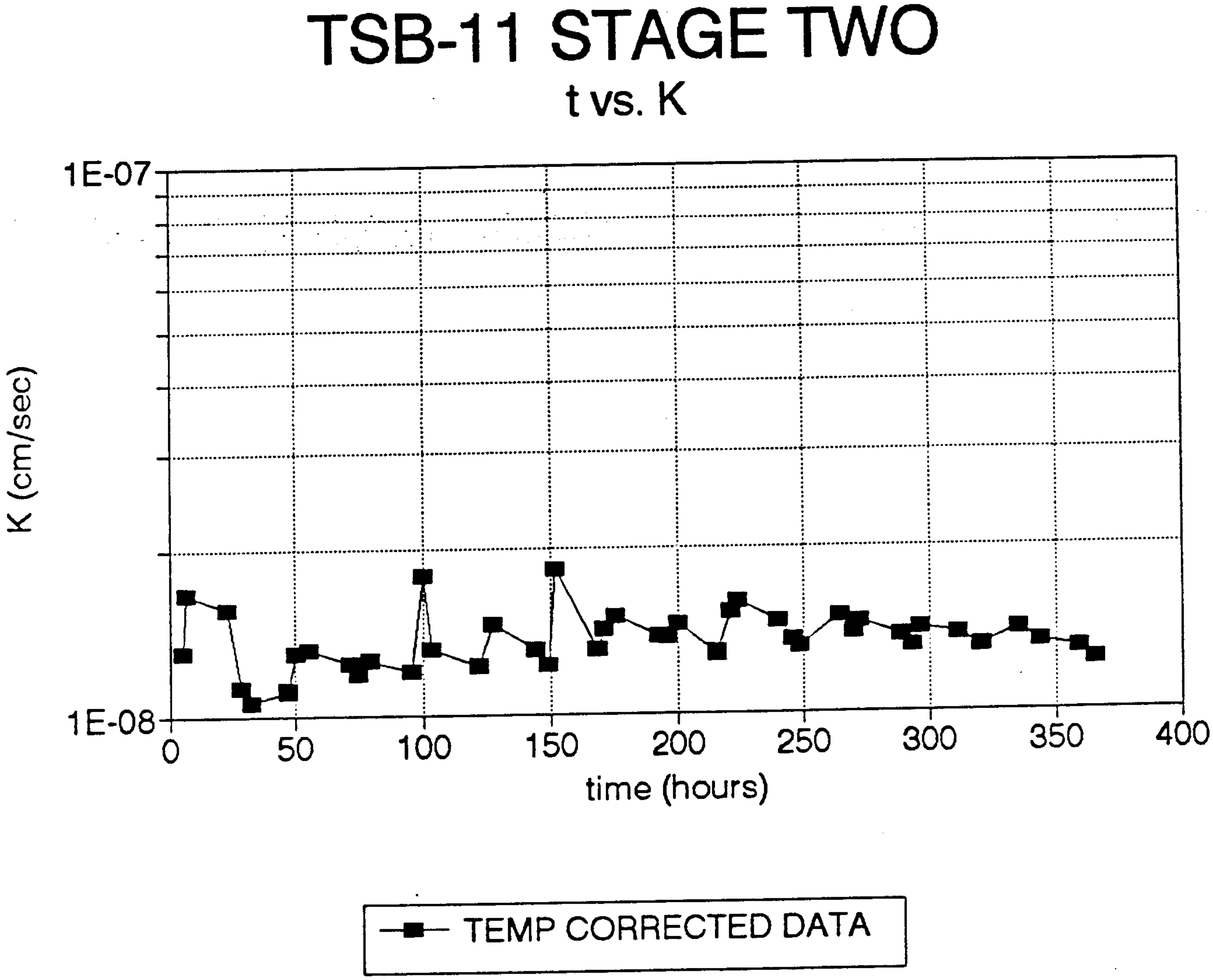

TSB-7 STAGE TWO
t vs. K
1E-08
1E-09
1E-10
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

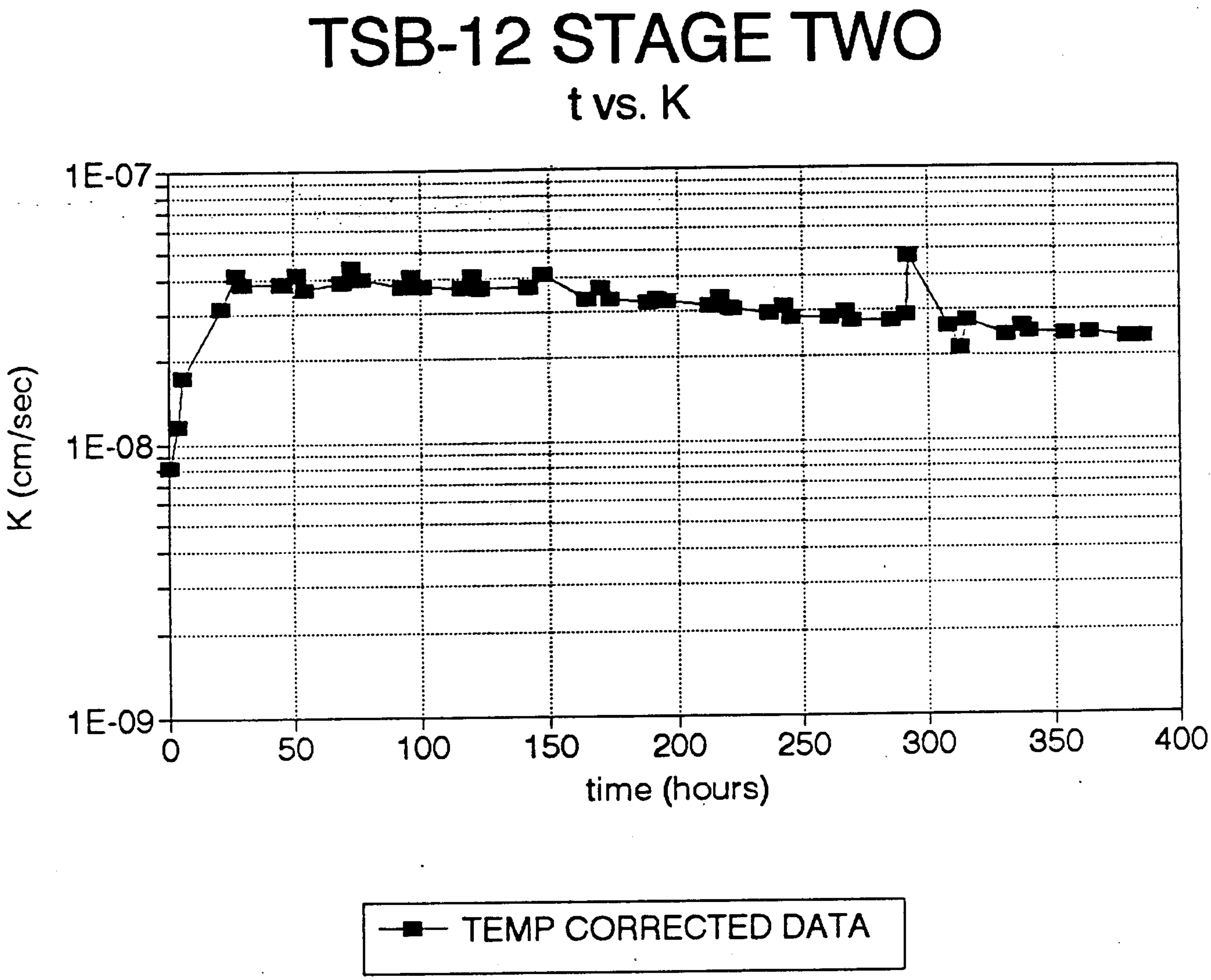

TSB-8 STAGE TWO
t vs. K
1E-07
1E-08
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

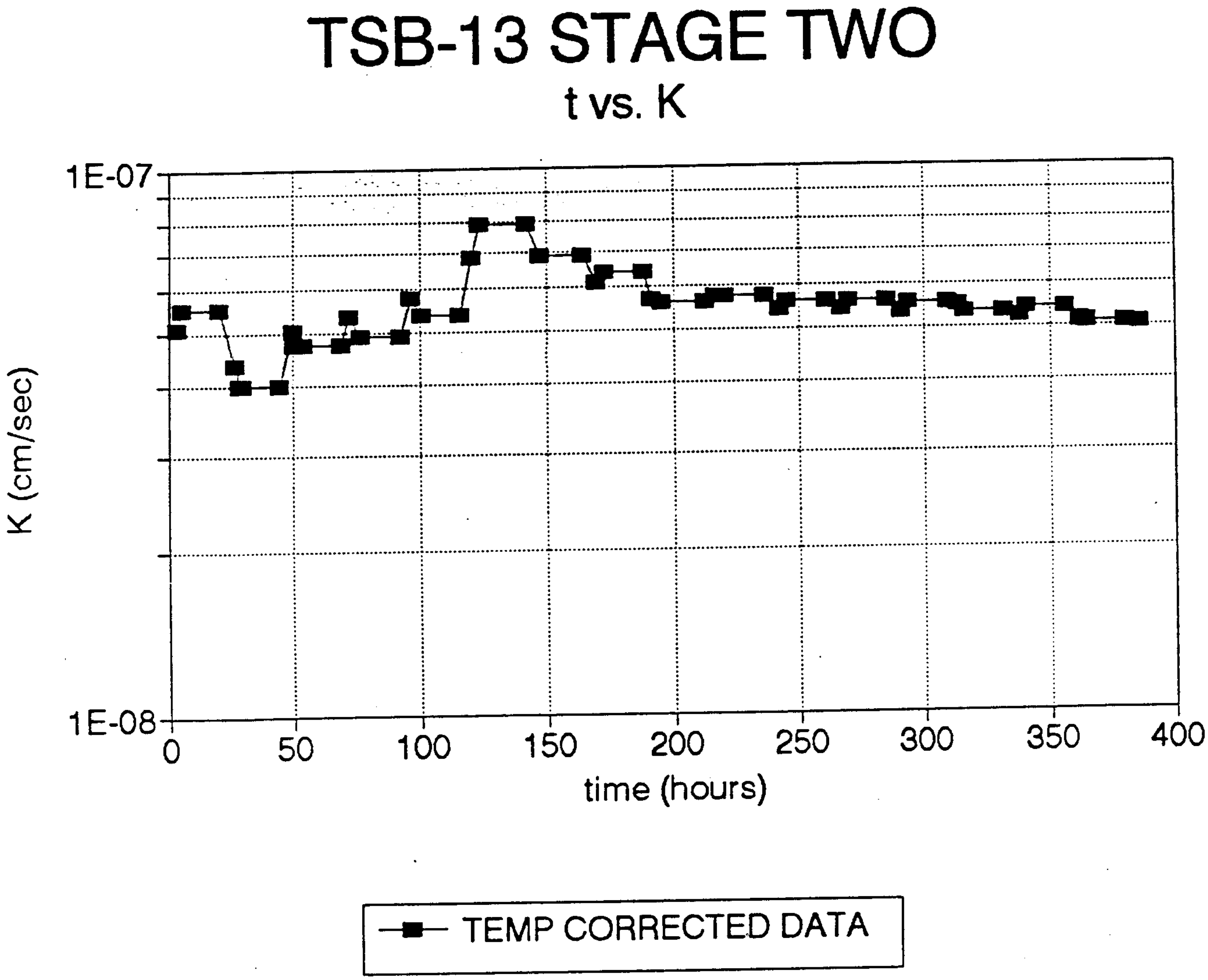
TSB-9 STAGE TWO

t vs. K



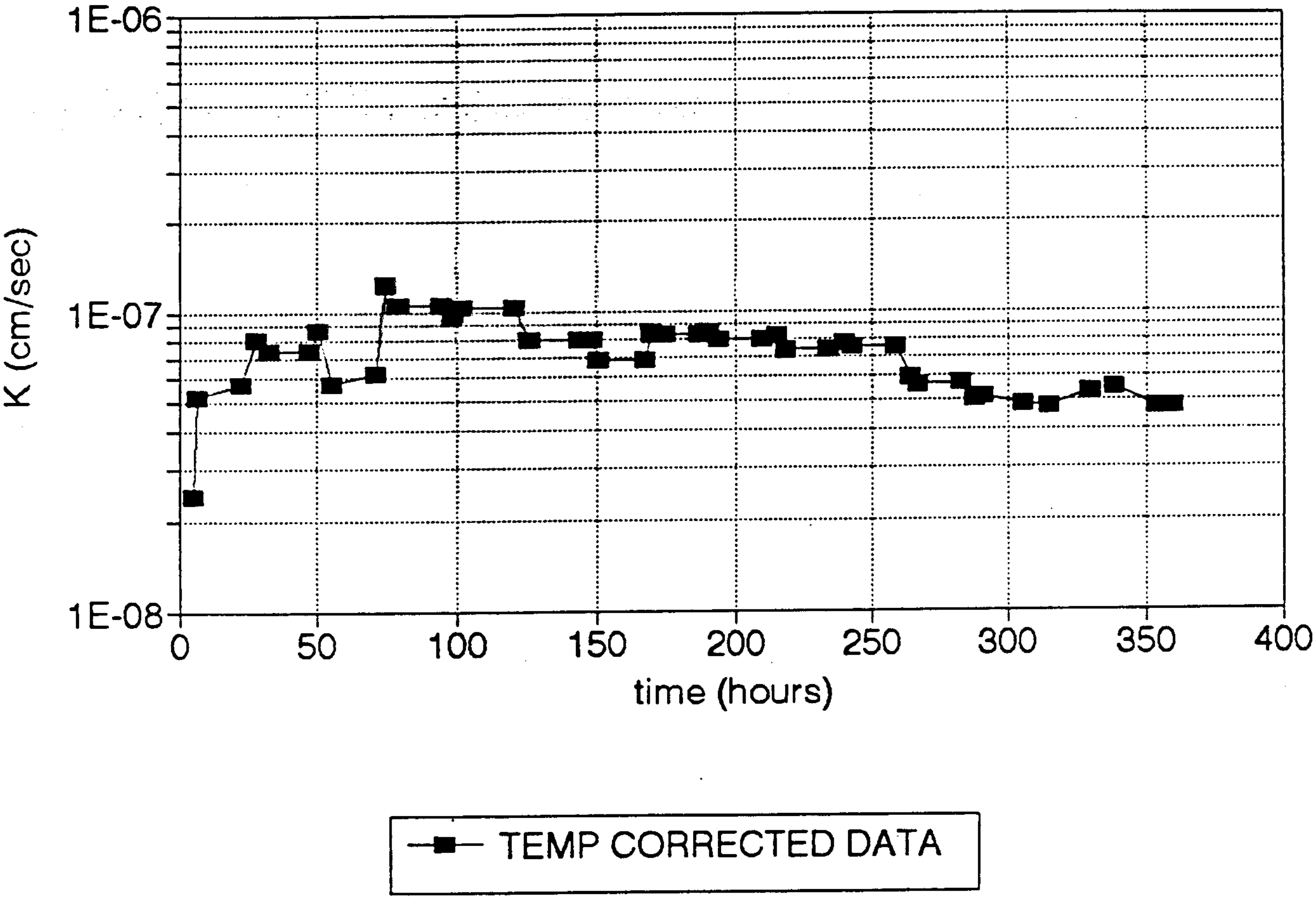

TSB-11 STAGE TWO
t vs. K
1E-07
1E-08
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA


TSB-12 STAGE TWO
t vs. K
1E-07
1E-08
1E-09
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA


TSB-13 STAGE TWO
t vs. K
1E-07
1E-08
K (cm/sec)
0
50
100
150
200
250
300
350
400
time (hours)
TEMP CORRECTED DATA

TSB-10 STAGE TWO

t vs. K



ATTACHMENT 4A

TSB CALCULATIONS

TIME-WEIGHTED AVERAGE

HYDRAULIC CONDUCTIVITY

K1′

CHECK

WSSRAP

SUBJECT STAGE I TSB FINAL VALUES SHEET 1/5

DATE 11-13-92 BY JDC CHKD. DE Conn... JOB NO. 3840-827-01-903

FROM BOUTWELL (1992):

$$K1' = \Sigma(K_i * T_i) / \Sigma(T_i)$$

WHERE:

$K1'$ = ARITHMETIC TIME WEIGHTED AVERAGE HYDRAULIC CONDUCTIVITY (cm/sec)

T_i = TIME DURATION OF TEST INCREMENT (i) (sec)

K_i = HYDRAULIC CONDUCTIVITY MEASURED DURING TEST INCREMENT (i) (cm/sec) (TEMPERATURE CORRECTED VALUES · KCT)

1) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-1}}$ WHERE $T_i > 1000$ s:

$$K1' = \frac{(4.4E-9 * 86400) + (3.49E-9 * 87900) + (3.38E-9 * 85020)}{86400 + 87900 + 85020 +}$$

$$\frac{+ (3.35E-9 * 82560) + (1.84E-9 * 91320) + (1.62E-9 * 76500)}{82560 + 91320 + 76500}$$

$$= \frac{1.54E-03}{509700} = \boxed{3.03E-09 \text{ cm/sec}}$$

2) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-2}}$ WHERE $T_i > 1000$ s

$$K1' = \frac{(2.55E-9 * 86280) + (3.22E-9 * 87660) + (3.25E-9 * 85140)}{86280 + 87660 + 85140 +}$$

$$\frac{+ (3.47E-9 * 82500) + (2.37E-9 * 91380) + (3.51E-9 * 76200)}{82500 + 91380 + 76200}$$

$$= 1.55E-03 / 509160 = \boxed{3.04E-09 \text{ cm/sec}}$$

CHECK

WSSRAP

SUBJECT STAGE 1 TSB FINAL VALUES SHEET 2/5

DATE 11-13-92 BY JDC CHKD. [illegible] JOB NO. 3840-827-01-903

3) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-3}$:

$$K1' = \frac{(2.58E-9 * 86580) + (2.18E-9 * 87660) + (2.43E-9 * 85080)}{86580 + 87660 + 85080}$$

$$\frac{+ (3.69E-9 * 82860) + (8.8E-10 * 91020) + (1.74E-9 * 83400)}{+ 82860 + 91020 + 83400}$$

$$= \frac{1.15E-3}{516600} = \boxed{2.23E-09 \text{ cm/sec}}$$

4) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-4}$:

$$K1' = \frac{(3.22E-9 * 86520) + (3.32E-9 * 87660) + (3.42E-9 * 85200) +}{86520 + 87660 + 85200}$$

$$\frac{(5.56E-9 * 82800) + (2.41E-9 * 91020) + (2.41E-9 * 82920)}{+ 82800 + 91020 + 82920}$$

$$= \frac{1.57E-03}{516120} = \boxed{3.05E-09 \text{ cm/sec}}$$

5) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-5}$:

$$K1' = \frac{(4.59E-9 * 85080) + (8.10E-9 * 82680) + (3.69E-9 * 91020)}{85080 + 82680 + 91020}$$

$$\frac{+ (4.08E-9 * 87600) + (5.52E-9 * 56400) + (2.99E-9 * 11100}{+ 87600 + 56400 + 11100}$$

$$= \frac{2.10E-03}{413880} = \boxed{5.07E-09 \text{ cm/sec}}$$

SUBJECT STAGE 1 TSB FINAL VALUES SHEET 3/5

DATE 11-13-92 BY JDC CHKD. [illegible] JOB NO. 3840-827-01-403

6) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-6}$:

$$K1' = \frac{(4.6E-9*85020)+(4.47E-9*82860)+(3.68E-9*91080)+(3.86E-9*87600)+(4.23E-9*56220)+(3.02E-9*12060)}{85020+82860+91080+87600+56220+12060}$$

$$= \frac{1.71E-03}{414840} = \boxed{4.12E-09 \text{ cm/sec}}$$

7) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-7}$:

$$K1' = \frac{(2.63E-9*85320)+(3.61E-9*82620)+(1.35E-9*90960)+(1.79E-9*87600)+(2.81E-9*56340)+(3.41E-9*4980)}{85320+82620+90960+87600+56340+4980}$$

$$= \frac{9.78E-04}{407820} = \boxed{2.40E-09 \text{ cm/sec}}$$

8) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-8}$ WHERE $T_i > 1000$ s:

$$K1' = \frac{(4.36E-9*82260)+(2.82E-9*91320)+(3.42E-9*87540)+(4.77E-9*85320)+(5.03E-9*56040)+(5.03E-9*5040)}{82260+91320+87540+85320+56040+5040}$$

$$= \frac{1.63E-3}{407520} = \boxed{4.00E-09 \text{ cm/sec}}$$

SUBJECT STAGE 1 TSB FINAL VALUES SHEET 4/5

DATE 11-13-92 BY JDC CHKD. J.C. Conner JOB NO. 3840-827-01-403

9) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-9}}$ WHERE $T_i > 1000s$:

$$K1' = \frac{(9.63E-9 * 85320) + (9.89E-9 * 82800) + (8.48E-9 * 90900) +}{85320 + 82800 + 90900 +}$$

$$\frac{+(8.72E-9 * 86100) + (9.56E-9 * 87660 + (1.22E-8 * 57000)}{86100 + 87660 + 57000}$$

$$= \frac{4.7E-3}{489780} = \boxed{9.59E-09 \text{ cm/sec}}$$

10) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-10}}$:

$$K1' = \frac{(5.66E-9 * 87660) + (6.42E-9 * 85320) + (6.5E-9 * 82920)}{87660 + 85320 + 82920 +}$$

$$\frac{(5.32E-9 * 90780) + (5.47E-9 * 86040) + (7.52E-9 * 57180)}{90780 + 86040 + 57180}$$

$$= \frac{2.97E-3}{489900} = \boxed{6.06E-09 \text{ cm/sec}}$$

11) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-11}}$:

$$K1' = \frac{(2.05E-9 * 87660) + (2.11E-9 * 85500) + (2.19E-9 * 82800) +}{87660 + 85500 + 82800}$$

$$\frac{(1.38E-9 * 90900) + (1.6E-9 * 85860) + (1.61E-9 * 57120)}{90900 + 85860 + 57120}$$

$$= \frac{8.96E-4}{489840} = \boxed{1.83E-09 \text{ cm/sec}}$$

CALC IV

SUBJECT STAGE I TSB FINAL VALUES SHEET 5/5

DATE 11-13-92 BY JDC CHKD. GE Conner JOB NO. 3840-877-01-903

12) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-12}}$:

$$K1' = \frac{(1.55E-9 * 86160) + (1.64E-9 * 88200) + (2.23E-9 * 84840)}{86160 + 88200 + 84840 +}$$

$$\frac{+(2.45E-9 * 82800) + (1.10E-9 * 91260) + (2.36E-9 * 59580)}{82800 + 91260 + 59580}$$

$$= \frac{9.11E-4}{492840} = \boxed{1.85E-09 \text{ cm/sec}}$$

13) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-13}}$:

$$K1' = \frac{(3.08E-9 * 82800) + (2.68E-9 * 87960) + (2.86E-9 * 85020) +}{82800 + 87960 + 85020}$$

$$\frac{(2.87E-9 * 82620) + (2.07E-9 * 91320) + (1.84E-9 * 59580)}{82620 + 91320 + 59580}$$

$$= \frac{1.27E-3}{489300} = \boxed{2.60E-09 \text{ cm/sec}}$$

ATTACHMENT 4B

TSB CALCULATIONS

TIME-WEIGHTED AVERAGE

HYDRAULIC CONDUCTIVITY

K2

CALCULATION NO. IV

SUBJECT STAGE 2 TSB FINAL VALUES SHEET 1/5

DATE 11-12-92 BY JDC CHKD. D E Conover JOB NO. 3840-827-01-903

FROM BOUTWELL (1992):

$$K2' = \Sigma(K_i \times T_i) / \Sigma(T_i)$$

WHERE: $K2'$ = ARITHMETIC TIME WEIGHTED AVERAGE HYDRAULIC CONDUCTIVITY (cm/sec)

T_i = TIME DURATION OF TEST INCREMENT (i) (sec)

K_i = HYDRAULIC CONDUCTIVITY MEASURED DURING TEST INCREMENT (i) (cm/sec) (TEMPERATURE CORRECTED VALUES - KCT)

1) USING LAST 5 MEASUREMENTS FROM $\boxed{\text{TSB-1}}$:

$$K2' = \frac{([illegible]1E\text{-}09 * 27{,}000) + (2.82E\text{-}09 * 55{,}020) + (2.73E\text{-}09 * 32{,}580)}{27000 + 55{,}020 + 32{,}580}$$

$$\frac{+ (2.91E\text{-}09 * 54{,}300) + (2.84E\text{-}09 * 32{,}040)}{+ 54{,}300 + 32{,}040} = \frac{5.63E\text{-}04}{200{,}940}$$

$$\boxed{= 2.8E\text{-}09 \text{ cm/sec}}$$

2) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-2}}$ WHERE $T_i > 1000$s:

$$K2' = \frac{(2.55E\text{-}8 * 54900) + (2.64E\text{-}8 * 32520) + (2.59E\text{-}8 * 54240) +}{54900 + 32520 + 54240}$$

$$\frac{(2.71E\text{-}8 * 31680) + (2.39E\text{-}8 * 54480) + (2.86E\text{-}8 * 22080)}{+ 31680 + 54480 + 22080}$$

$$= \frac{6.46E\text{-}03}{249900} \quad \boxed{= 2.58E\text{-}08 \text{ cm/sec}}$$

CALC No IV

SUBJECT STAGE 2 TSB FINAL VALUES SHEET 2/5

DATE 11-12-92 BY JDC CHKD. D E Conover JOB NO. 3840-827-01-903

3) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB\ 3}$:

$$K2' = \frac{(3.82E-09 * 55080) + (2.93E-09 * 32460) + (3.66E-09 * 51480) +}{55080 + 32460 + 51480}$$

$$\frac{(2.20E-09 * 31920) + (2.94E-09 * 54660) + (2.95E-09 * 22800)}{+ 31920 + 54660 + 22800}$$

$$= \frac{8.01E-04}{251400} = \boxed{3.19E-09\ cm/sec}$$

4) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-4}$:

$$K2' = \frac{(6.20E-09 * 55080) + (5.93E-09 * 32460) + (5.65E-09 * 54480) +}{55080 + 32460 + 54480}$$

$$\frac{(5.10E-09 * 31920) + (5.06E-09 * 54660) + (5.12E-09 * 22800)}{+31920 + 54660 + 22800}$$

$$= \frac{1.4E-03}{251400} = \boxed{5.56E-09\ cm/sec}$$

5) USING LAST 6 VALUES FROM $\boxed{TSB-5}$:

$$K2' = \frac{(1.65E-09 * 56280) + (1.19E-09 * 31260) + (1.38E-09 * 54360}{56280 + 31260 + 54360 +}$$

$$\frac{+ (1.62E-09 * 31920) + (1.86E-09 * 55980) + (3.05E-09 * 20940}{31920 + 55980 + 20940}$$

$$= \frac{3.13E-4}{250740} = \boxed{1.24E-09\ cm/sec}$$

$$\frac{4.25E-4}{250740} = 1.69E-09\ cm/sec$$

CALC No. IV

WSSRAF

SUBJECT STAGE 2 TSB FINAL VALUES SHEET 3/5

DATE 11-13-92 BY JDC CHKD. [illegible] JOB NO. 3840-827-01-903

6) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-6}}$ WHERE $T_i > 1000s$:

$$K2' = \frac{(1.25E-8 * 56280) + (1.17E-8 * 31260) + (1.31E-08 * 54240) + (1.18E-08 * 31920) + (1.15E-08 * 55800) + (1.16E-08 * 21120)}{56280 + 31260 + 54240 + 31920 + 55800 + 21120}$$

$$= \frac{3.04E-3}{250620} = \boxed{1.21\ E-08\ cm/sec}$$

7) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-7}}$:

$$K2' = \frac{(1.90E-9 * 55680) + (8.84E-10 * 31920) + (1.82E-09 * 54300) + (8.92E-10 * 31860) + (1.30E-09 * 55200) + (1.69E-9 * 21720)}{55680 + 31920 + 54300 + 31860 + 55200 + 21720}$$

$$= \frac{3.7E-04}{250680} = \boxed{1.47E-09\ cm/sec}$$

8) USING LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB 8}}$ WHERE $T_i > 1000s$:

$$K2' = \frac{(5.19E-8 * 55740) + (4.82E-8 * 31860) + (4.05E-8 * 54240) + (4.1E-8 * 31800) + (3.75E-8 * 55140) + (3.9E-8 * 21660)}{55740 + 31860 + 54240 + 31800 + 55140 + 21660}$$

$$= \frac{1.08E-2}{250440} = \boxed{4.33E-08\ cm/sec}$$

CALC No IV

SUBJECT STAGE 2 TSB FINAL VALUES SHEET 4/5

DATE 11-13-92 BY JDC CHKD. J.E. C[illegible] JOB NO. 3840-827-01-903

9) USING THE LAST 6 MEASUREMENTS FROM $\boxed{TSB-9}$ WHERE $T_i > 1000s$

$$K2' = \frac{(1.79E-7 * 54060) + (1.56E-7 * 21780) + (1.63E-7 * 10140) + (1.63E-7 * 54060) + (1.61E-7 * 6180) + (1.62E-7 * 16560)}{54060 + 21780 + 10140 + 54060 + 6180 + 16560}$$

$$= \frac{2.72E-2}{162780} = \boxed{1.67E-07 \text{ cm/sec}}$$

10) USING LAST 6 MEASUREMENTS FROM $\boxed{TSB-10}$ WHERE $T_i > 1000s$:

$$K2' = \frac{(4.89E-8 * 54360) + (4.75E-8 * 33000) + (5.34E-8 * 54000) + (5.52E-8 * 32100) + (4.78E-8 * 54060) + (4.73E-8 * 22920)}{54360 + 33000 + 54000 + 32100 + 54060 + 22920}$$

$$= \frac{1.25E-2}{250440} = \boxed{5.01E-8 \text{ cm/sec}}$$

11) USING THE LAST 6 MEASUREMENTS FROM $\boxed{TSB-11}$:

$$K2' = \frac{(1.38E-8 * 54480) + (1.32E-8 * 33060) + (1.41E-8 * 54000) + (1.34E-8 * 32100) + (1.30E-8 * 54120) + (1.24E-8 * 22920)}{54480 + 33060 + 54000 + 32100 + 54120 + 22920}$$

$$= \frac{3.37E-3}{250680} = \boxed{1.34E-08 \text{ cm/sec}}$$

CALC No IX

SUBJECT STAGE 2 TSB FINAL VALUES SHEET 5/5

DATE 11-13-92 BY JDC CHKD. DE Conner JOB NO. 3840-827-01-90?

12) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB 12}}$ WHERE $T_i > 1000s$)

$$K2' = \frac{(2.58E-8 * 22860) + (2.47E-8 * 9660) + (2.42E-8 * 54180)}{22860 + 9660 + 54180}$$

$$\frac{+ (2.46E-8 * 32040) + (2.35E-8 * 54540) + (2.37E-8 * 22200)}{+ 32040 + 54540 + 22200}$$

$$= \frac{4.74E-03}{195480} = \boxed{2.42E-08 \text{ cm/sec}}$$

13) USING THE LAST 6 MEASUREMENTS FROM $\boxed{\text{TSB-13}}$ WHERE $T_i > 1000s$

$$K2' = \frac{(5.43E-8 * 9660) + (5.42E-8 * 54300) + (5.13E-8 * 22560)}{9660 + 54300 + 22560 +}$$

$$\frac{+ (5.11E-8 * 9480) + (5.10E-8 * 54540) + (5.05E-8 * 22200)}{9480 + 54540 + 22200}$$

$$= \frac{9.01E-03}{172740} = \boxed{5.22E-08 \text{ cm/sec}}$$

ATTACHMENT 5

SPREADSHEET CALCULATION SUMMARY

Kh AND Kv

TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST
STAGE ONE and STAGE TWO DATA REDUCTION
and CALCULATION of Kv and Kh VALUES
WSSRAP SUPPORTING STUDY 3A –
HYDRAULIC PROPERTIES OF UNDISTURBED SOILS

TSB INSTALLATION	K1' (cm/sec)	K2' (cm/sec)	K2'/K1'	p*	L (inches)	m**	Kv	Kh	Kh/Kv	Comments
TSB-01	3.03E-09	2.80E-09	0.9241	1	6.00	0.7410	4.09E-09	2.25E-09	0.5491	Best Kh & Kv
TSB-01	3.03E-09	2.80E-09	0.9241	2	6.00	0.9953	3.04E-09	3.02E-09	0.9906	
TSB-02	3.04E-09	2.58E-08	8.4868	1	6.25	30.7055	9.90E-11	9.33E-08	942.8277	
TSB-02	3.04E-09	2.58E-08	8.4868	***	6.25	3.3360	9.11E-10	1.01E-08	11.1289	Best Kh & Kv
TSB-03	2.23E-09	3.19E-09	1.4305	1	6.38	2.0560	1.08E-09	4.58E-09	4.2271	
TSB-04	3.05E-09	5.56E-09	1.8230	1	6.13	3.3360	9.14E-10	1.02E-08	11.1289	
TSB-05	5.07E-09	1.69E-09	0.3333	***	6.00	3.3360	1.52E-09	1.69E-08	11.1289	
TSB-06	4.12E-09	1.21E-08	2.9369	1	6.88	6.8060	6.05E-10	2.80E-08	46.3216	
TSB-06	4.12E-09	1.21E-08	2.9369	***	6.88	3.3360	1.24E-09	1.37E-08	11.1289	Best Kh & Kv
TSB-07	2.40E-09	1.48E-09	0.6167	10	5.88	1.1470	2.09E-09	2.75E-09	1.3156	Best Kh & Kv
TSB-07	2.40E-09	1.48E-09	0.6167	20	5.88	2.0630	1.16E-09	4.95E-09	4.2560	
TSB-08	4.00E-09	4.33E-08	10.8250	1	6.25	43.2103	9.26E-11	1.73E-07	1867.1300	
TSB-08	4.00E-09	4.33E-08	10.8250	***	6.25	3.3360	1.20E-09	1.33E-08	11.1289	Best Kh & Kv
TSB-09	9.59E-09	1.67E-07	17.4140	1	5.75	82.0455	1.17E-10	7.87E-07	6731.4641	
TSB-09	9.59E-09	1.67E-07	17.4140	****	5.75	1.1470	8.36E-09	1.10E-08	1.3156	Best Kh & Kv
TSB-10	6.06E-09	5.01E-08	8.2673	1	5.88	31.8615	1.90E-10	1.93E-07	1015.1552	
TSB-10	6.06E-09	5.01E-08	8.2673	*****	5.88	0.7410	8.18E-09	4.49E-09	0.5491	Best Kh & Kv
TSB-11	1.83E-09	1.34E-08	7.3224	1	6.00	26.9140	6.80E-11	4.93E-08	724.3634	
TSB-11	1.83E-09	1.34E-08	7.3224	***	6.00	3.3360	5.49E-10	6.10E-09	11.1289	Best Kh & Kv
TSB-12	1.85E-09	2.42E-08	13.0811	1	6.38	54.0530	3.42E-11	1.00E-07	2921.7268	
TSB-12	1.85E-09	2.42E-08	13.0811	****	6.38	1.1470	1.61E-09	2.12E-09	1.3156	
TSB-12	1.85E-09	2.42E-08	13.0811	*****	6.38	0.7410	2.50E-09	1.37E-09	0.5491	Best Kh & Kv
TSB-13	2.59E-09	5.22E-08	20.1544	1	6.75	88.7885	2.92E-11	2.30E-07	7883.3977	
TSB-13	2.59E-09	5.22E-08	20.1544	***	6.75	3.3360	7.76E-10	8.64E-09	11.1289	Best Kh & Kv

* Values for p from Table on Page 21 (Boutwell, 1992).
** From FORTRAN Program which solves for the given K2'/K1' using selected values for m
*** m value for these TSBs is from TSB-04, closest TSB in depth and unit tested, with a < 20 Kh/Kv ratio.
**** m value for these TSBs is from TSB-07.
***** m value for this TSB is from TSB-01.

ATTACHMENT 6

TSB METHOD REFERENCE

THE STEI TWO-STAGE BOREHOLE FIELD PERMEABILITY TEST

by: Gordon P. Boutwell, PhD, P.E.

Presented to

"CONTAINMENT LINER TECHNOLOGY AND SUBTITLE D"

Seminar Sponsored by
Geotechnical Committee
Houston Branch, ASCE

Houston, Texas - March 12, 1992

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SYNOPSIS

In 1991, the Texas Department of Health began requiring field verification of the hydraulic conductivity for the waste-retention barriers under its jurisdiction. The TDH has approved two procedures: the Two-Stage Borehole (TSB) method and the Sealed, Double-Ring Infiltrometer (SDRI) method. The TSB method is discussed herein.

It is a falling-head infiltration test conducted in a cased borehole, typically 4 inches in diameter. The first stage is performed with the bottom of the hole flush with the bottom of the casing for maximum effect of vertical permeability (k_v). After steady-state is achieved, the hole is advanced some 6 to 8 inches below the bottom of the casing so that horizontal permeability (k_h) has a greater effect. The two stages yield the following:

Stage 1 - The maximum possible value for (k_v).
Stage 2 - The minimum possible value for (k_h).
Stage 1 + Stage 2 - Constants for two equations which can then be solved for the real (k_h, k_v).

Procedures are available for reduction of the data in the cases of both above and below water table testing, and for the bottom boundary conditions of a material far more permeable, equally permeable, or far less permeable than the medium being tested. The test has been successful in evaluating both compacted and natural materials with permeabilities as low as 1x10(-9) cm/sec.

The major test precautions include proper sealing of the casing along the outside, accounting for temperature effects, and correcting for sidewall smear during the second stage. The test is quick, simple, and relatively inexpensive. It allows results in days, rather than months. Multiple installations are feasible so that statistical confidence can be achieved. It is recognized in the literature, including U.S. EPA publications, and accepted by many State regulatory authorities.

I. INTRODUCTION

Clay barriers are an important component of waste retention structures. Their primary geotechnical characteristic for this use is hydraulic conductivity, which must be verified during the Construction Quality Assurance program. Until recently, practice relied on laboratory testing of small (7 to 10 cm diameter) undisturbed samples taken from the barrier or a similarly constructed test pad. Day and Daniel (1985) reported conductivities measured in the field which were 3 to 4 orders of magnitude higher than they obtained with laboratory tests. While that study was justly criticized, the horse was out of the barn and regulators all over the country galloped into field testing for hydraulic conductivity evaluation at waste facilities.

From the regulatory standpoint, a test procedure should be accurate and avoid false positives, i.e., not indicate compliance with the specified conductivity when the liner or pad truly has a higher value. This normally means testing a large soil volume searching for the elusive "macropores" which are thought to evade, somehow, even numerous laboratory tests. The regulated community wants the accuracy and avoidance of false positives for their own protection, but also wants to minimize testing times (and costs), and to avoid false negatives, both for economy.

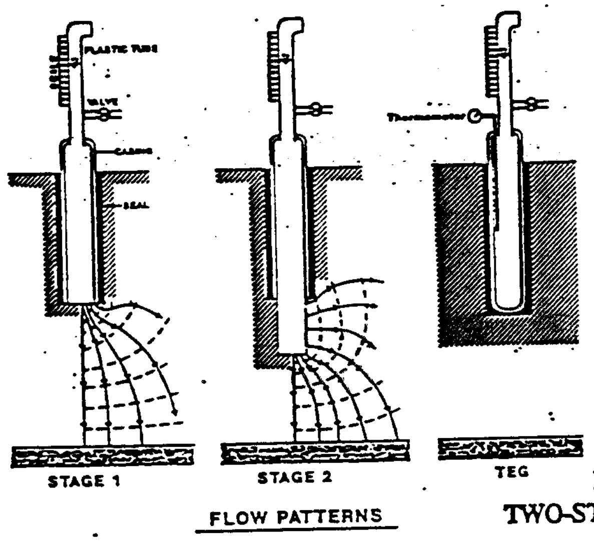
In about the last two years, two methods have become accepted as meeting these criteria to a satisfactory degree: the Sealed, Double-Ring Infiltrometer (SDRI) and the Two-Stage Borehole (TSB) procedure. Each has its stronger and weaker points (see Daniel, 1989).

II. BASIC CONCEPTS

The vertical conductivity (k_v) governs flow, even in sidewall liners if built in the preferred manner: lifts parallel to the slope. However, the horizontal conductivity (k_h) is greater than the vertical. All field tests are affected by this anisotropy, unless flow in the horizontal direction is artificially blocked; the effect is to increase the test conductivity by factors of 2 to 5 over the real (k_v) value. Equations for flow from various source geometries in a cross-anisotropic medium are available in Hvorslev (1951). However, each equation has two unknowns: (k_v) and ($m^2 = k_h/k_v$).

The TSB procedure combines four old concepts into one new idea to find (k_v). The field procedure is taken from long-established US Bureau of Reclamation methods: their flush-bottom borehole test (E-18) and borehole packer test (E-19). Computations are based on the Hvorslev equations adapted for various bottom boundary conditions by the three-dimensional Image Potential Technique (Carslaw and Jaeger, 1959). The new idea is performing both USBR tests in the same borehole, yielding two equations which can be solved for the two unknowns, (k_h) and (k_v).

The TSB is a field infiltration test, conducted in a cased borehole so that the geometry of the infiltrating zone can be controlled. It is normally conducted as a falling-head test. The basic idea is to vary the geometry of the infiltrating area so as to vary the relative effects of (k_h) and (k_v). In the first stage, the geometry is chosen so that (k_v) has its maximum effect. The second stage geometry is such that (k_h) has its maximum effect. The results of the two stages yield two equations in two unknowns (k_h, k_v), which can then be solved. This concept is illustrated on Figure 1, below:



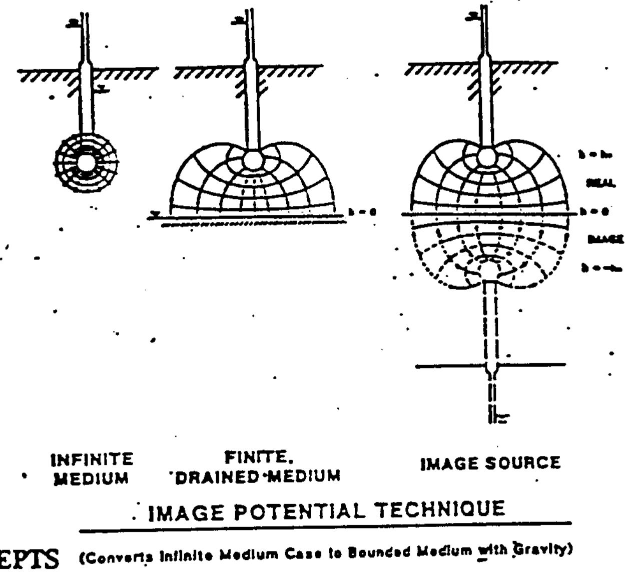


FIGURE 1
TWO-STAGE CONCEPTS

Stage 1 is normally conducted using a flat bottom flush with the base of the casing. Infiltration proceeds until a steady-state flow condition is achieved. Then, the borehole is advanced some 1.5 to 2 casing diameters (6 to 8 inches) below the bottom of the casing. The apparatus is refilled, and infiltration in this Stage 2 continues until it achieves steady-state flow.

During the test, the soil is assumed isotropic ($k_v = k_h$). Stage 1 then yields an apparent permeability (K1), and Stage 2 a different value (K2). The unknown ratio (k_h/k_v) is a unique function of the known test geometry and the known test ratio (K2/K1). When the former is determined, the real (k_v, k_h) can be computed from (K1) or (K2).

III. FIELD PROCEDURES

As is the case with virtually all field tests, and especially field permeability tests, the field procedures are of paramount importance. The most diligent office analyses cannot overcome all of the problems resulting from improper installation, inadequate monitoring, premature test termination, and the like.

3.1 Test Program Design. The test program should be designed to meet the conditions assumed in deriving the data reduction equations so that meaningful results can be obtained.

3.1.1 Vertical Boundaries. Certain clearances are required between the infiltrating surface and any boundaries, pervious or impervious. These can be summarized as:

a. **Minimum casing embedment below ground surface** **= 2.5D**
(Prevents uplift, minimizes hydraulic fracturing)

b. **Minimum thickness of tested material below bottom of Stage 2= 2.0D**
(Avoids violating boundary conditions of equations)

c. **Minimum recommended Stage 2 extension** **= 1.5D**
(Avoids theoretical problems at finite but small L/D)

D = Casing inside diameter
L = Length of Stage 2 extension

3.1.2 Horizontal Spacings. It is intuitively obvious that the tests must be spaced "far enough" apart so that their flows do not interfere with each other causing a falsely low permeability. Also, the presence of a drainage boundary (such as the edge of a test pad) which is "too close" to the test will increase the flow, yielding a falsely high permeability.

This can be avoided by maintaining at least the following clearances:

a. **Minimum horizontal distance between tests** **= 30D**
b. **Minimum horizontal distance to free surface** **= 30D**

3.1.3 Number and Size of Tests. The number of tests required for evaluation depends on the project, the acceptance criteria, and the variability of the stratum/fill being evaluated. As in virtually any other geotechnical testing, "the bigger the better".

However, the general practice has been to use 4-inch (ID) tests, with 5 tests for the typical liner or test pad.

The scale effect, if any, of test size has not been fully researched. Virtually all of the known tests have been conducted using 4-inch (10 cm) ID casings. These tests typically permeate a volume of some 0.4 - 1.1 cubic feet each, or 2 to 5 cubic feet for a 5-test group. Benson (pers. comm., 1991) indicates that the minimum representative volume for a permeability determination is on the order of 0.5 - 1.0 cubic foot. This is about the volume permeated by a typical TSB test.

3.1.4 Other Details. There are a few other details in test planning which should be considered. Among these are:

a. Protect the test area surface from desiccation, usually with clear or white plastic.
(Avoids heat-induced problems).

b. Use a "sock" to prevent collapse of the Stage 2 open hole in susceptible materials. The sock is a rigid cylinder of open-mesh plastic, lined with a filter geofabric. The cylinder is somewhat smaller in diameter than the casing ID (and thus the Stage 2 hole), and an inch or so longer than the extension for Stage 2. It is fitted with retrieving lines and not left in the hole after the test.

c. Minimize the distance (R_z) from the ground surface to the bottom of the measuring scale, especially for shallow tests. This also aids in having the longest possible reading time between standpipe refills and avoiding hydraulic fracturing.

d. Match the standpipe size to the flow rate so that accuracy is achieved but overnight readings are possible. For a 4-inch casing, this usually means a 0.5 - 0.75 inch ID standpipe.

3.2 Permeameter Installation. Proper installation and checking the permeameters are vital to obtaining a valid test. Various field techniques have been developed through experience which minimize problems. These techniques are discussed in this section.

3.2.1 Permeameter. A typical permeameter is illustrated on Figure 2. The apparatus is simple; the permeameter can be assembled with a visit to a water-well driller and a hardware store. The elements for a falling-head system are:

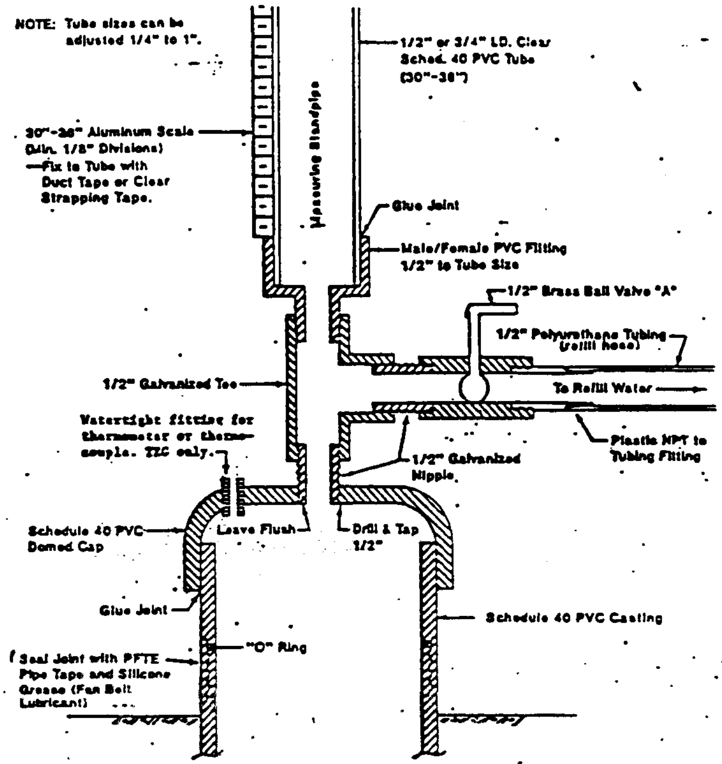
a. Casing. Typically 4-inch ID Schedule 40 PVC monitoring well pipe, flush-threaded, with "O"-Ring joint. Other casings can be used.

b. Cap. To fit casing, preferably domed, and drilled and/or tapped to receive the standpipe apparatus.

c. Standpipe. *Clear* Schedule 40 PVC or acrylic tube, 0.5 to 1.0 inch ID, with scale. Include elbow with cover (having air-vent) to prevent rain entry and minimize evaporation.

d. Fittings. The small fittings necessary to assemble the apparatus.

All joints which are not glued are assembled with PTFE Plumber's Tape and silicone grease (not sealant).



THIS HAS BEEN SIMPLIFIED, SEE FINAL SHEET

FIGURE 2
TYPICAL PERMEAMETER

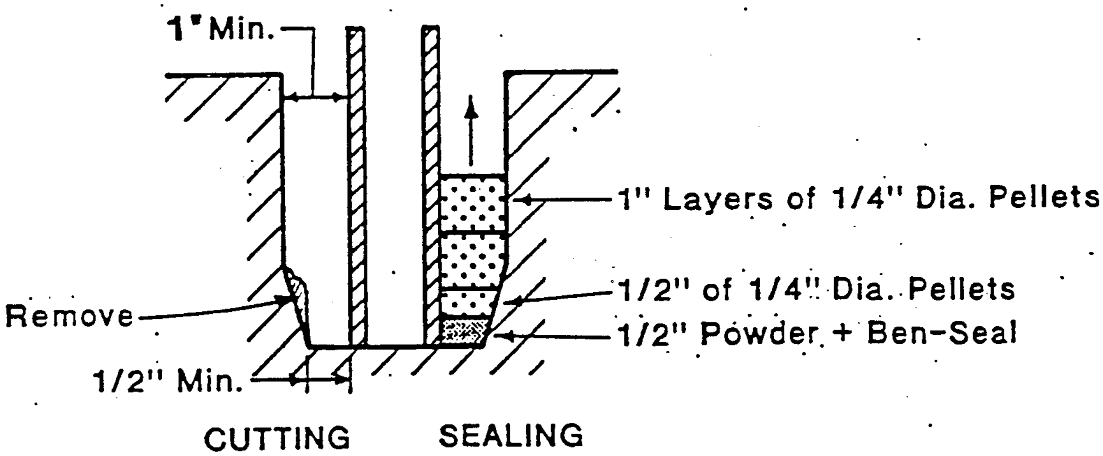


FIGURE 3
SEALING PROCEDURE

3.2.2 Borehole. The casing is set into a borehole. The holes have been drilled using rigs, power-operated hand equipment, and hand augers. The device depends on depth and hardness of material. The hole must have a large enough diameter to allow sealing the annular space between the borehole wall and the casing. Also, it must not disturb the soils below the casing bottom. The bottom must also be flat. Experience has shown the following to be acceptable:

a. **Borehole diameter at least 2 inches greater than the casing OD. (To allow sealant to reach the bottom and for tamping).**

b. **Stop point of auger about 1 inch above proposed casing bottom. (To avoid testing in a disturbed material)**

c. **Ream bottom of borehole to final depth with a flat auger.**

The bottom of the borehole should be flat and flush with the bottom of the casing in order to correspond with Hvorslev's (or H-I) Case "B" or "C" for Stage 1.

3.2.3 Sealing. This is the single most important step in installation. A poorly sealed test cannot be salvaged. The annular space between the casing and the wall of the borehole is sealed with bentonite. Best results have been attained using 1/4" (not 3/8" or larger) bentonite pellets or crushed bentonite (Baroid "Hole-Plug" or equivalent). The procedure, illustrated on Figure 3, is:

a. **Crush sufficient pellets, "Ben-Seal", or "Hole-Plug" to fill about 1/2 inch of the annulus. This should have about 1/16" size fragments with some powder.**

b. **Place this material into the annular space.**

c. **Place about 1/2 inch of bentonite pellets or "Hole-Plug" into hole,**

d. **Tamp the bentonite pellets or "Hole Plug",**

e. **Add water until it shows above the bentonite,**

f. **Repeat the process (but using only the pellets or "Hole Plug") in 1 inch increments to the ground surface or a minimum of 6D above the casing bottom, whichever occurs first. Grouting above the 6D level is allowable.**

g. **Allow the bentonite (and grout) to hydrate at least overnight.**

The casing must be steadied to prevent lateral motion while sealing. The bentonite seal is then allowed to hydrate overnight before any head is applied to the system.

3.2.4 Advancing for Stage 2. Upon completion of Stage 1, a borehole is advanced below the bottom of the casing to form the cylindrical infiltrating surface for Stage 2. The important points are:

a. **Do not disturb the casing - that can affect the seal.**

b. **Borehole diameter should equal casing ID.**

c. **Stop point of auger about 1 inch above proposed Stage 2 bottom. Ream flat and measure depth.**

d. **Roughen the sidewalls to minimize smear.**

This portion of the work is normally handled with hand equipment. The first step after removing the cap is to empty the casing of water (tests above groundwater level or where no seepage was noted during Stage 1 drilling and/or sealing). It is frequently useful to obtain an undisturbed sample during this process, using ASTM D2937 or D1587. However, undisturbed sampling should not be performed if the material being tested contains gravel-sized particles; they can disturb the sidewalls during the push or driving. After or in lieu of undisturbed sampling, the boring is augered until the point of the auger is about 1 inch above the desired bottom for Stage 2. The auger should be at least 1/2 inch in diameter smaller than the casing ID. The boring is then completed to depth and diameter with a flat-bottomed reamer.

The reamer is designed to minimize sidewall smear, having full casing ID only at the cutting edge. The sidewalls are then roughened with a wire brush or similar device, a procedure also recommended in USBR E-18. This step must not be omitted, since one of the significant problems encountered in Two-Stage testing has been artificially low values for Stage 2 due to smear. Equations to handle smear are included herein, but require some idea of the degree of smear.

After the borehole is completed and cleaned of cuttings, the depth is measured so that the correct length of the Stage 2 cylinder is known. For a typical test, a 1-inch depth error will yield the wrong Stage 2 permeability value by 7 to 8%. The cap is then reseated, and Stage 2 begins.

3.3 Ambient Condition Effects. Temperature changes cause the dominant effects of ambient conditions on this test, although there may be some contribution from barometric pressure changes. Temperature changes affect the test by:

* Volumetric changes in the water and apparatus.
* Viscosity changes with temperature.
* Freezing the test water.

The procedures for overcoming these effects are given below.

3.3.1 Volumetric Effects (TEG). At slow rates of flow, the field readings are affected by temperature, as has been noted on many such projects. Rising temperature causes the water column in the pressure/measurement standpipe to expand, so that the drop in water level is less than flow alone would produce. The net effect is a lower apparent permeability. Conversely, falling temperature produces a higher apparent permeability. A normal day's temperature variations can easily cause a 0.5 to 1 order of magnitude change in the apparent permeability of low-permeability materials.

Therefore, a complete "dummy" test setup is installed but with the bottom of the casing sealed with a cap which is normally glued on and pressure-tested. This dummy, or temperature effect gauge (TEG) is of the same construction and embedded to the same depth as the regular test setups. Since there is no flow from the TEG, any change in its readings must be due to changes in the ambient conditions (temperature and/or barometric pressure). Such changes would affect the regular test setups to exactly the same degree.

This correction is applied to the regular tests by:

* Reading the TEG at the same times as readings are taken on the regular tests.
* Determining any increase (decrease) in water levels in the TEG between regular test readings.
* Subtracting any increase (adding any decrease) at the TEG from the readings at the regular tests for the ends of the same time increments.

3.3.2 Viscosity Effects of Temperature. Permeability is normally reported as the value for water at 20°C (68°F). The density and viscosity of liquids, including water, are affected by temperature. The effect on permeability is in direct ratio to the kinematic viscosity (U), which is the viscosity divided by the density. The kinematic viscosity decreases at higher temperatures. The net effect is that the apparent permeability is greater than the 68°F value at low temperatures. The reverse occurs with decreasing temperatures. The effects for ordinary conditions can be from -50% to +15% on the permeability value. The normal correction to the standard condition is given in ASTM D5084:

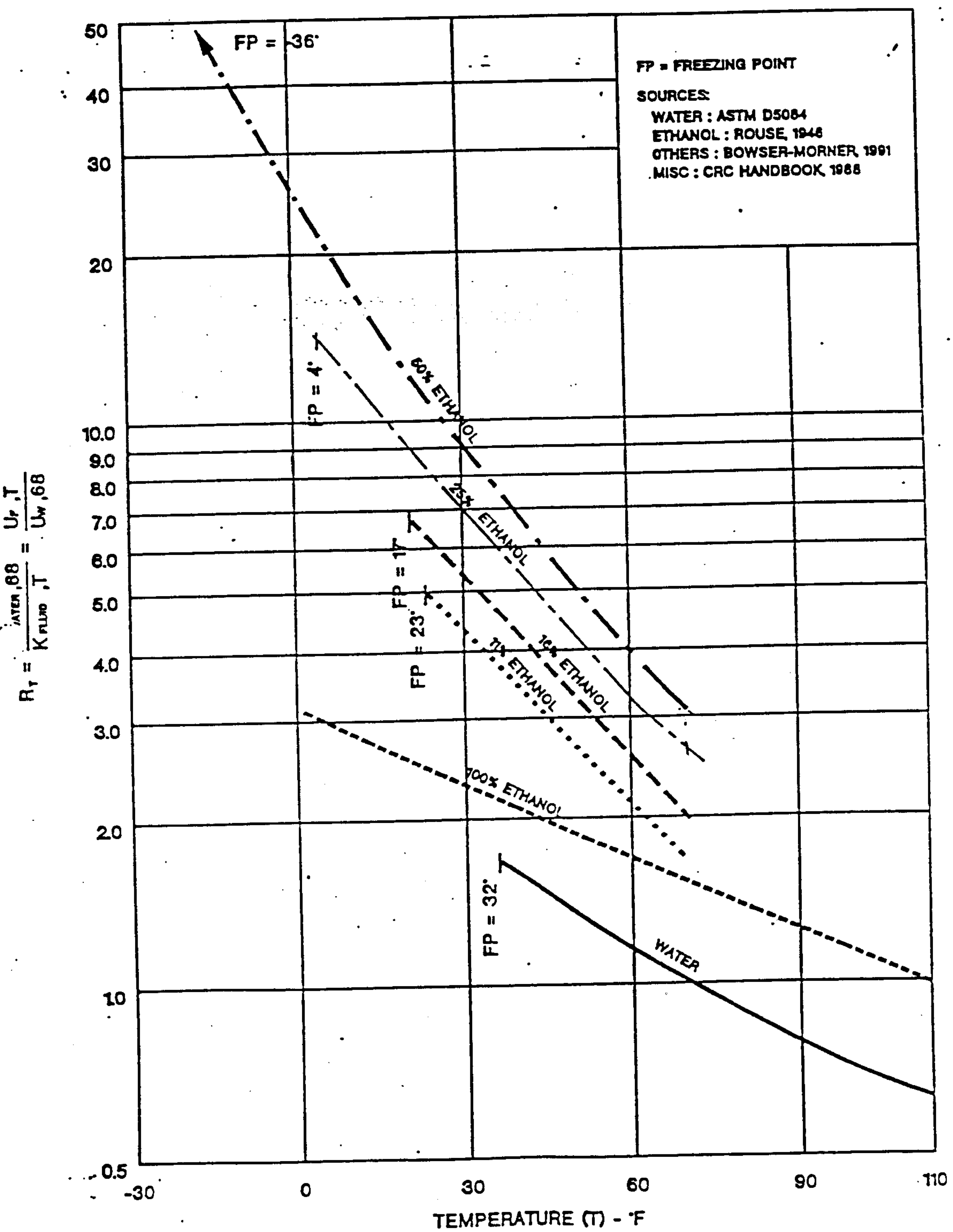


FIGURE 4
KINEMATIC VISCOSITY FACTORS

$$k_s/k_T = R_T = U_T/U_s \qquad (3.3.-1)$$

where:
k_s = Permeability for water at 68°F
k_T = Permeability observed in test
R_T = Correction Factor
U_T = Kinematic viscosity for test fluid at test temperature
U_s = Kinematic viscosity for water at 68°F

The factors (R_T) are given for water at temperatures between freezing and 120°F (0 to 49°C) in ASTM D5084. See also Figure 4 which reproduces that data.

The temperature of the exfiltrating water is measured by a thermometer or thermocouple in the TEG. It should extend to roughly the bottom of the casing. The thermometer or the leads for the thermocouple should have its own (sealed) port into the TEG cap or casing. Running either through the TEG standpipe could easily affect its function of volumetric correction.

3.3.3 Freezing Conditions. Unfortunately, field testing must sometimes proceed when the air temperatures are below freezing. Landfill operators often complete a test pad in late fall, so that they will have approval from the regulators for construction in the spring. Even if the ground temperatures stay above freezing, one cannot get decent readings from a frozen standpipe. Three procedures have been used:

a. Insulate the exposed test equipment, exposing only to make readings. (Only if mean daily air temperature exceeds freezing)

b. Use an antifreeze. (Ethanol as Vodka is good, but needs its own R_T vs temperature graph. Does not attack clay at 25% or less alcohol).

c. Heat the test units. (Potential for different temperatures - can invalidate the TEG).

3.4 Conducting the Test. The following discussion is applicable to both Stage 1 and Stage 2. Basically, the procedure is:

a. Fill and assemble permeameters. (Use PTFE tape and silicone grease. Pour slowly to avoid bottom erosion).

b. **Read standpipe levels over time at the permeameter, plus level and temperature at the TEG.**
(Levels: to 1/16", temperature to 1°F).

c. **Convert these readings to apparent permeabilities.**

d. **Continue the test until these permeabilities remain steady.**

3.5 Field Calculations - Apparent Permeability. The data from each reading is converted into an apparent permeability, termed (K1) for Stage 1 and (K2) for Stage 2. Keeping up with the data in terms of a permeability has a physical meaning, and also yields a better "feel" for the behavior of the medium being tested. If that medium were isotropic ($k_h = k_v$), then (K1,K2) would be "the" permeability. Remember that the objective of most field permeability tests on regulated facilities is to determine that the vertical permeability (k_v) of the liner is not greater than some value, usually 1x10(-7) cm/sec, or to show that the horizontal permeability (k_h) of a drainage material is not less than some value, typically 1x10(-2) cm/sec. It can be shown that (K1) is the maximum possible value for (k_v) and that (K2) is the minimum possible value for (k_h). Hence, using these apparent permeabilities (K1,K2) frequently allows "pass-or-fail" determination early in the testing process. For example, (K1<Spec) within 24 hours in 90% of tests where (k_v/Spec<0.6), and 70% of all tests.

The equations for both Stage 1 and Stage 2 follow the generic falling-head test format:

$$k = R_T G \, Ln(H_1/H_2)/(t_2-t_1) \tag{3.5-1}$$

where:

where:	k	=	Permeability
	H_1	=	Initial head (at $t=t_1$)
	H_2	=	Final head (at $t=t_2$)
	t_1	=	Initial time
	t_2	=	Final time
	G	=	Geometric Constant, depends on test geometry
	R_T	=	Kinematic viscosity correction to water at 68°F

In both Stages, the head is taken as the distance from the level in the standpipe to the groundwater level. The distance from the bottom of the casing to the groundwater level is limited for calculation purposes (only) to no more than 20 times the casing ID. If the depth to groundwater is less than 20 times the casing ID, the true depth is used in the calculations. However, where the depth to groundwater exceeds this criterion, it is considered to be at this 20-diameter depth in the calculations. This limitation is derived by 3-dimensional analogy with the two-dimensional "effective radius" of a well. The volumetric effects of temperature are accounted for using a corrected final head, replacing (H_2) by (H_2'), where:

$$H_2' = H_2 - c \tag{3.5-2}$$

where: c = Increase in TEG standpipe water level during time period from t_1 to t_2

If the TEG standpipe water level goes up between readings, (c) is positive and ($H_2' < H_2$). Conversely, (c) is negative and ($H_2' > H_2$) if the TEG standpipe level drops between readings. This step is not theoretically precise, but is close enough for test purposes. The theoretical solution yields a complex implicit equation in which the true permeability is a function of its own logarithm. However, for the geometry of the test setups and the observed magnitudes of increases/decreases, the apparent permeabilities calculated in this manner differ from the true permeabilities by no more than 2 to 5 percent. The net result is to "smooth" the apparent permeabilities. This smoothing is most apparent (and most useful) when the soil's apparent permeability is less than about 2 to 5x10(-7) cm/sec and especially for small-diameter standpipes.

The kinematic viscosity factor (R_T) used in the calculation is that for the average test water temperature during the period from (t_1) to (t_2).

3.5.1 Stage 1. The nomenclature for the various terms of the Stage 1 calculations is illustrated on Figure 5. The proper equation is given below; it is the solution for (k_v) for an isotropic medium ($k_h/k_v = 1$).

$$K1 = R_T(\pi d^2/11D_1)[1 + a(D_1/4b_1)]Ln(H_1/H_2')/(t_2 - t_1) \tag{3.5-3}$$

where:
- d = ID of Standpipe
- D_1 = Effective diameter of Stage 1 (Casing ID or OD)
- b_1 = Depth of tested medium below bottom of casing
- a = +1 for impervious lower boundary
- a = 0 for infinite depth of tested medium ($b_1 = \infty$)
- a = -1 for pervious lower boundary

And the other terms are as defined above. For field use, the geometric terms are combined into a single constant:

$$K1 = R_T\, G1\, Ln(H_1/H_2')/(t_2 - t_1) \tag{3.5-4}$$

where: $G1 = (\pi d^2/11D_1)[1 + a(D_1/4b_1)]$

A complete example is given in the Sample Calculations, Appendix A.

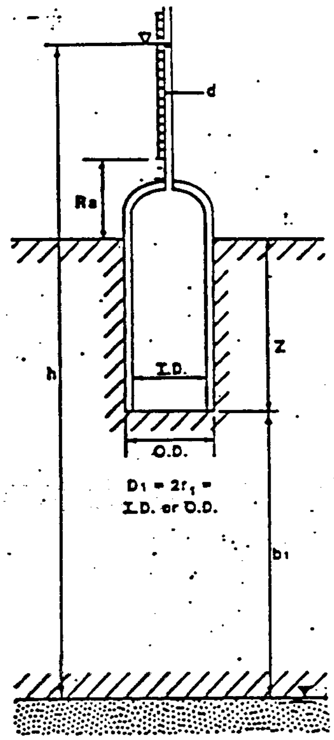


FIGURE 5
STAGE 1 NOMENCLATURE

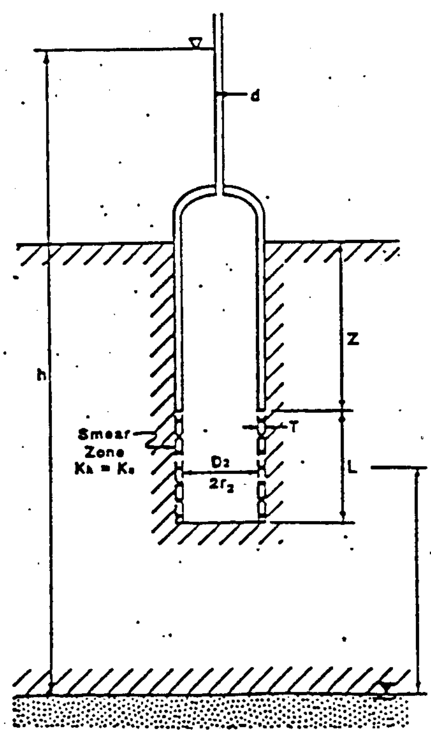


FIGURE 6
STAGE 2 NOMENCLATURE

3.5.2 Stage 2. The nomenclature for the various terms of the Stage 2 calculations is illustrated on Figure 6. The proper equation is that given below; it is the solution for (k_v) with the assumption that ($k_h/k_v = 1$).

$$K2 = R_T\,(d^2/16Lf)\,\{Ln[u(1,r_o,o)] + a\,Ln[u(1,r_o,2b_2)]\}\,Ln(H_1/H_2')/(t_2-t_1) \qquad (3.5\text{-}5)$$

where:

f	=	$1-0.5623\,Exp(-1.566\,L/D)$
L	=	Length of Stage 2 cylinder below casing
$u(1,r_o,o)$	=	$\{L/D_2 + \sqrt{1+(L/D_2)^2}\}^2$
$u(1,r_o,2b_2)$	=	$\dfrac{4b_2/D_2+L/D_2+\sqrt{1+(4b_2/D_2+L/D_2)^2}}{4b_2/D_2-L/D_2+\sqrt{1+(4b_2/D_2-L/D_2)^2}}$
D_2	=	Diameter of Stage 2 extension (normally casing ID)
b_2	=	Distance from center of Stage 2 extension to underlying boundary

And the other terms are as defined previously. The factor (f) was introduced to account for the non-convergence of the Hvorslev equations as ($L \rightarrow 0$). For field use, the geometric terms are combined into a single constant:

$$K2 = R_T\,G2\,Ln(H_1/H_2')/(t_2-t_1) \qquad (3.5\text{-}6)$$

where: $G2 = (d^2/16Lf)\,\{Ln[u(1,r_o,o)] + a\,Ln[u(1,r_o,2b_2)]\}$

A complete example is given in the Sample Calculation, Appendix A.

3.5.3 Time-Weighted Averaging. Whether one uses the Laplacian or the Green-Ampt model for groundwater flow, there are still transient effects at the beginning of every type of field or laboratory permeability test. The observed effect is to indicate a high permeability, gradually decreasing to some relatively constant value corresponding to a steady-state flow condition. Such an effect is usually noted in the TSB. Therefore, the test must be conducted "long enough" to achieve virtually the steady-state condition or the results will be not only too high but also erratic. In addition, a single value each of (K1) and (K2) must be used in the final data reduction (Section IV).

There is no reliable method for pre-calculating the length of time required to achieve steady-state. Rather, the observational method is used. The appropriate apparent permeability (K1 or K2) is calculated for each time increment, and/or over longer periods of time; when these appear to be stable, they are checked using arithmetic time - weighted averages, e.g.,

$$K' = \Sigma\ (TiKi)/\Sigma\ (Ti) \tag{3.5-7}$$

where: K' = Arithmetic Time-Weighted Average (ATWA) Permeability
Ti = Time Duration of Test Increment (i)
Ki = Permeability Measured during Test Increment (i)

This is theoretically exact for a single run (between refills). Time - weighted averaging also provides a rational basis for smoothing the (often) slightly erratic individual (K1,K2) values from the various time increments. An example of time-weighted averaging is given in the Sample Calculations, Appendix A.

3.5.4 Termination Criteria. Infiltration theory indicates that the apparent permeabilities (K1,K2) should forever decrease at an ever-and-ever decreasing rate. Observations in over 200 of these tests show that a steady-state condition or a close approximation of it is achieved in reasonable testing periods. A log-log plot of apparent permeability versus time is useful in determining when steady-state is achieved. Eventually, the (K1,K2) plots fluctuate about stable values. An example of such a plot is given in the Sample Calculation, Appendix A. This plot illustrates the importance of fairly closely spaced readings at the beginning of each stage, which allow separating the long-term behavior from the short-term fluctuations, i.e., enhance the "signal-to-noise" ratio.

In most tests, time-weighted averages become quite stable, often to within 1 to 5%. A reasonable set of criteria for terminating a stage is as follows:

* The time-weighted averages do not show an upwards or downwards trend with time,

and

* Do not fluctuate more than 10 to 20% among themselves,

and

* Maintain this behavior over a "sufficiently long" time, 12 - 72 hours depending on permeability.

IV.- DATA REDUCTION

4.1 Basic Procedure. In some cases, the (K1') or (K2') values may be adequate for the purpose of the test. More generally, the test is performed to determine the actual (k_h,k_v). This section outlines how to convert the (K1',K2') values calculated as outlined in Paragraphs (3.5.1) and (3.5.2) into the real permeabilities (k_h,k_v). Details for the common case are covered below.

4.1.1 Simultaneous Equations. The equations presented earlier for determining (K1,K2) are special cases of more general relationships. These more general equations define the degree of anisotropy by the parameter:

$$m = \sqrt{k_h/k_v} \qquad (4.1\text{-}1)$$

This parameter affects the geometric terms of the various equations. Each stage has its own equation with a different effect of (m). In a general sense, these can be written as:

Stage 1: $k_v = G1_m \, Ln(H_1/H_2')(t_2-t_1)$
$K1 = G1 \, Ln(H_1/H_2')(t_2-t_1)$

or $$k_v = K1\,(G1_m/G1) \qquad (4.1\text{-}2)$$

where: $G1_m$ = Geometric factor including (m)

Similarly, for Stage 2,

$$k_v = K2'\,(G2_m/G2) \qquad (4.1\text{-}3)$$

If the soil medium being tested is homogeneous (although cross-anisotropic and possibly bounded), the vertical permeability (k_v) must be the same in both stages. Hence, (4.1-2) and (4.1-3) provide two equations in the two unknowns ($m = \sqrt{k_h/k_v}$) and (k_v). The resulting equation is:

$$K1'(G1_m/G1) = k_v = K2'(G2_m/G2)$$

or $$K2'/K1' = (G1_m/G1)(G2/G2_m) \qquad (4.1\text{-}4)$$

The standpipe area (A_p) cancels for each individual stage in (4.1-2 and 4.1-3), even though different (A_p) values may have been used for Stage 1 and Stage 2, and even for different portions of either stage. The actual equations for the geometric constants involving (m) are given in Paragraph (4.2).

The ratio (K2'/K1') is known from the test; the actual values introduced are the long-term time-weighted averages, (K1' and K2'). The geometric terms are also known. Therefore, Equation (4.1-4) is satisfied only for one value of (m). Due to the complex nature of (4.1-4), trial-and-error or graphical solution works best for specific problems.

4.1.2 Calculating (k_h) and (k_v). The value for (m) is obtained as outlined above in Paragraph (4.1.1). When (m) is known, (k_v) can be calculated directly from Equation (4.1-2), and, by the definition of (m) in Equation (4.1-1).

$$k_h = m^2 k_v \tag{4.1-5}$$

4.1.3 Stage 1 Only Method. In some individual tests, the ratio (K2'/K1') is so low that Equation (4.1-4) fails to converge. Others may have so large a (K2'/K1') ratio that the permeability values are obviously in error: (k_v) is far too low and (k_h) is far too high. This is usually due to inhomogeneity of the tested material. Advancing Stage 2 into a zone of lower permeability will cause a low (K2'/K1'). Conversely, advancing into a zone of higher permeability (such as a poor lift joint in fill or a silt/sand seam in natural materials) yields a very high (K2'/K1').

These events are handled by using a conservative (m) from the best-behaved tests and introducing that value into Equation (4.1-2).

4.2 Image Equation with Smear. The basic Hvorslev equations apply most directly to masses of infinite depth and below the groundwater level. Neither test pads nor liners often meet these criteria. Therefore, results calculated by using the Hvorslev equations directly for such cases will not be correct. For a given permeability, both proximity to a drainage zone and the vertical gradient due to gravity cause the flow to be greater than the basic Hvorslev equations would predict. The basic Hvorslev equations therefore predict a higher permeability than the material really has. The vertical gradient effect can be overcome by using the head as from the top of the standpipe to the groundwater level. A method for accounting for the proximity effect and proving the previous assertion was needed.

The method of image wells has been used in geohydrology for years. The classic example is the solution for a well near a river, found in many textbooks. However, the method is not limited to two-dimensional situations such as this illustration. Any solution for an infinite or semi-infinite medium which describes the potential field (head distribution) can be converted to a solution for a finite medium bounded by a plane by using the Image Potential technique (Carslaw & Jaeger, 1959).

The basic idea is that halfway between a source and a sink of equal but opposite strength will be a plane of zero potential. So, if there is a plane of zero potential (head), its effect can be replaced by an "image" source/sink located twice as far away from the sink/source as is the midway plane. If the test (source) is set a distance (b) above the drainage blanket, the flow field will be the same as if there were no blanket but there was an image test (sink) with negative head at a distance of (2b) below the real test. Since the drainage blanket is at zero head, the head at the test is taken as the total head lost: (b) plus the excess pressure (ht) applied at the infiltration point of the test.

Consider also the case where both the real and image sources have equal strengths and both are sources (positive head) or both are sinks (negative head). By the same logic as given above, the midway plane will be a no-flow boundary, corresponding to an impermeable bottom boundary located at a depth (b) below the real test.

4.2.1 Stage 1. The Hvorslev-Image equation (Case "C") for the flush-bottomed portion of the test is given by:

$$k_v = (\pi d^2/11mD_1)[1+a(D_1/4mb_1)]Ln(H_1/H_2')/(t_2-t_1) \qquad (4.2\text{-}1)$$

where:

d	=	ID of Standpipe
D_1	=	Test diameter for Stage 1
b_1	=	Thickness of test medium below base of casing
H_1	=	Initial head ($t=t_1$)
H_2'	=	Corrected final head = H_2-c (see Paragraph 3.5)
t_2	=	Final time
t_1	-	Initial time
a	=	-1 for permeable bottom boundary
a	=	0 for infinite depth to bottom boundary
a	=	+1 for impermeable bottom boundary

Equation (4.2-1) can also be written as:

$$k_v = G1_m \, Ln(H_1/H_2')/(t_2-t_1) \qquad (4.2\text{-}2)$$
$$G1_m = (\pi d^2/11mD_1)[1+a(D_1/4mb_1)]$$

4.2.2 Stage 2. Similarly, for the cylindrical case (Hvorslev "G"), the Image equation (with sidewall smear) is that given by:

$$k_v = (d^2/16Lfm^2)\{Ln[u(m,r_o+T,o)] + a\,Ln[u(m,r_o,2b_2)] + p\,Ln[u(m,r_o,o)/u(m,r_o+T,o)]\}\,Ln(H_1/H_2')/(t_2-t_1) \qquad (4.2\text{-}3)$$

where:

L	=	Length of Stage 2 extension
f	=	$1\text{-}0.5623\ \mathrm{Exp}(-1.566\ L/D)$
$u(m,r_o,o)$	=	$[mL/D_2 + \sqrt{1+(mL/D_2)^2}]^2$
$u(m,r_o,2b_2)$	=	$\dfrac{4mb_2/D_2+mL/D_2+\sqrt{1+(4mb_2/D_2+mL/D_2)^2}}{4mb_2/D_2-mL/D_2+\sqrt{1+(4mb_2/D_2-mL/D_2)^2}}$
$u(m,r_o+T,o)$	=	$\{mL/(D_2+2T) + \sqrt{1+[mL/(D_2+2T)]^2}\}^2$
p	=	k_h/k_s
k_s	=	Permeability of smeared zone
T	=	Thickness of smeared zone (0.6cm=0.25in)
D_2	=	Diameter of Stage 2 extension
b_2	=	Distance from <u>center</u> of Stage 2 cylinder to underlying boundary

And the other terms are as defined above for Stage 1. Equation (4.2-3) can be written in the generic format as:

$$k_v = G2S\ Ln(H_1/H_2')/(t_2-t_1) \qquad (4.2\text{-}4)$$

where: $G2S = (d^2/16Lfm^2)\{Ln[u(m,r_o+T,o)] + a\ Ln[u(m,r_o,2b_2) + p\ Ln[u(m,r_o,o)/u(m,r_o+T,o)]\}$

The generic expression for (K2'/K1') as a function of the test geometry is Equation (4.1-4). Following the steps outlined in Paragraph (4.1.1),

$$K2'/K1' = (G1_m/G1) \bullet (G2/G2S) \qquad (4.2\text{-}5)$$

where:

$$(G1_m/G1) = (1/m)\ [1+a(D_1/4mb_1)]/[1+a(D_1/4b_1)]$$

$$(G2/G2S) = \frac{m^2\{Ln[u(1,r_o,o)]+aLn[u(1,r_o,2b_2)]}{Ln[u(m,r_o+T,o)]+aLn[u(m,r_o,2b_2)]+pLn[u(m,r_o,o)/u(m,r_o+T,o)]}$$

Equation (4.2-5) is solved by taking an appropriate (p) and determining (m) by trial-and-error or by a graphical solution such as Figure 7.

The value of (p) is not determined in the test. The normal range of (p) is from 2 to 20; (p=1) indicates no smear. The following values for (p) have yielded satisfactory results, consistent with apparently non-smeared tests on the same tested units:

K2'/K1'	p
>1.1	1
0.9 - 1.1	1,2
0.8 - 0.9	2,5
0.7 - 0.8	5,10
0.6 - 0.7	10,20
0.4 - 0.6	15,20
0.4>	*

* Use Stage 1 Only Approach - Paragraph (4.1.3).

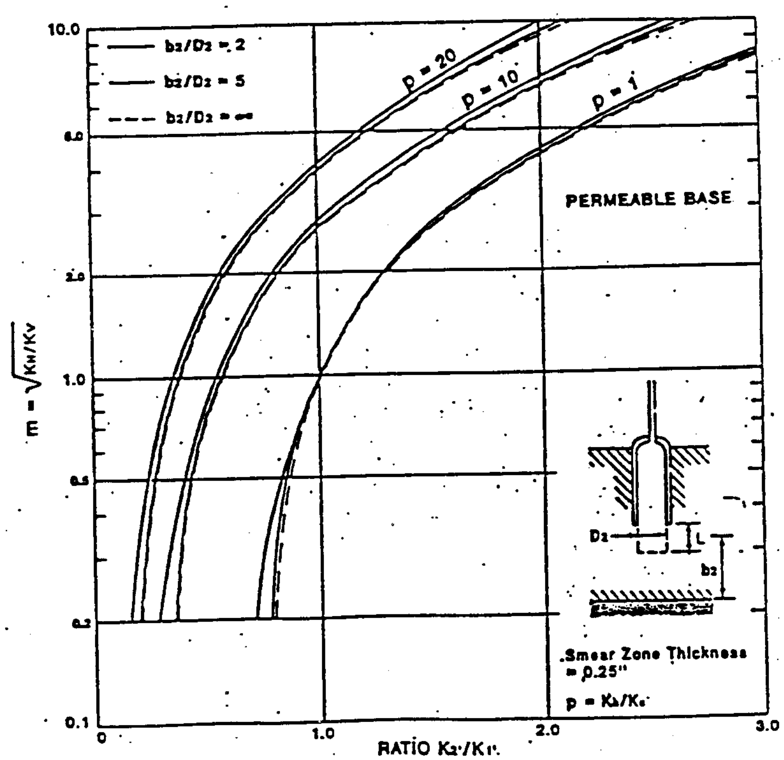


FIGURE 7
GRAPH FOR (m) - (L/D=1.5)

4.3 Non-Saturated Media. Field permeability tests are frequently performed on materials which are not fully saturated. Such materials affect the tests in two ways:

- The hydraulic head is dissipated over the (changing) distance from the point of inflow into the soil to the "wetting front", where the soil is considered fully saturated (Green-Ampt Model).

- Unsaturated clays exhibit "soil suction", which effectively adds to the hydraulic head.

In the Two-Stage test, infiltration into the soil is three-dimensional. The majority of the head loss occurs close to the inflow surface, even in a fully saturated material. About 50% of the loss occurs within one test radius of the inflow surface. For a typical Two-Stage test, disregarding wetting front distance theoretically yields a permeability 10 to 50% too high.

The effect of soil suction is roughly proportional to the ratio of suction to applied head. The effect of suction alone on a permeability test can be expressed as:

$$k_a/k_t = (1 + S/h_o) \qquad (4.3\text{-}1)$$

where:

	k_a	=	Observed permeability
	k_t	=	True saturated permeability
	S	=	Soil suction
	h_o	=	Applied head

The Two-Stage test normally operates with heads 3 to 6 times those of other test methods, minimizing the relative effect of suction.

These two effects can be handled using the graph presented on Figure 8. That figure is based on numerical solutions for the equipotential surfaces in an infinite medium (a=0). However, for the typical real test, the dimensionless flow volume is such that the equipotentials do not vary significantly from the ellipsoids in either the permeable-base (a=-1) or impermeable-base (a=+1) cases. The actual volume, which includes an allowance for the impermeable casing, has been included on Figure 8.

When using Figure 8, the initial volume (V_o) is taken as:

- Stage 1 - The volume of a hemi-ellipsoid having the diameter (D_1) and height ($D_1/4$).

$$V_{o1} = (\pi/24)\, D_1^3 \qquad (4.3\text{-}2)$$

- Stage 2 - The volume of the Stage 2 cylinder.

$$V_{o2} = (\pi/4)\, D_2^3\, (L/D_2) \qquad (4.3\text{-}3)$$

WE ALMOST NEVER USE NON-SAT EFFECTS.

The term (V_w) is the total volume of water which has infiltrated into the soil through the end of each stage, allowing for that removed in the Stage 2 extension. The (n_a) term is the soil's air porosity.

Figure 8 is applied first to the individual (K1) values from Stage 1:

$$K1_t = K1/[R(1+s/H_o)] \qquad (4.3\text{-}4)$$

where: $K1_t$ = K1 corrected for suction and wetting front
R = Permeability ratio from Figure 8

Then, Figure 8 is similarly applied to the individual (K2) values from Stage 2:

$$K2_t = K2/[R(1+s/H_o)] \qquad (4.3\text{-}5)$$

where: $K2_t$ = K2 corrected for suction and wetting front

Thereafter, ($K1_t$,$K2_t$) are used in Equation (3.5-7) for the average values ($K1'_t$,$K2'_t$). These are then introduced into Equations (4.2-5) for (m) then (4.1-2) for (k_v), and finally (4.1-5) for (k_h).

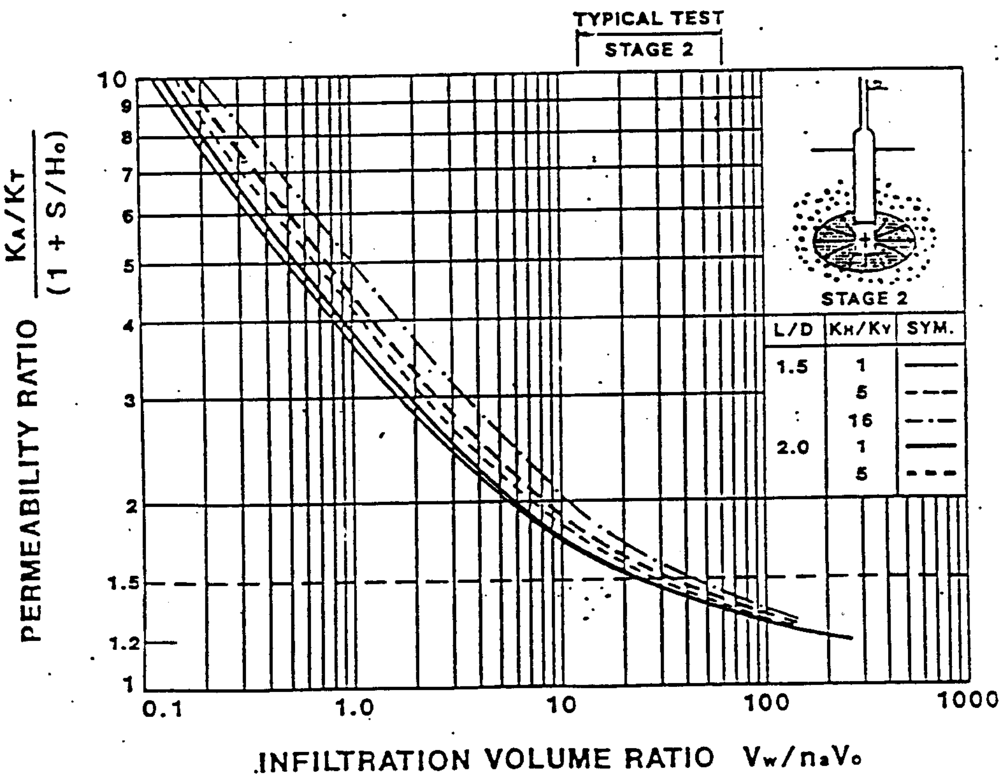


FIGURE 8
NON-SATURATION EFFECTS

V. EXPERIENCE WITH TSB TESTS

As of January, 1992, STEI alone has been involved in some 200 tests (40+ projects) on recompacted materials and 90 tests (6 projects) in natural materials. These have generally been of relatively low permeability [10(-6) to 10(-9) cm/sec]. Some conclusions from this experience are given below.

5.1 Types of Projects. The test has been successful in many types of soils:

5.1.1 Test Pads and Liners. It has been used in such conditions for test units from 20 to 60 inches thick. Materials have ranged from CH-OH (Liquid Limit 100+, clay content 70%+) to SC/GC (Liquid Limit 30-, gravel content up to 30%, clay content 12%). Vertical permeabilities have been successfully measured from the mid 10(-7)'s to the low 10(-9)'s (values in cm/sec).

5.1.2 "Natural" Deposits. It has been very successful in clays to depths of 10 to 15 feet. Where the clay does not make water, it has also been successful to about 20 to 25 feet. The test was moderately successful in soft, highly layered mine tailings clay at depths up to 30 feet. It has been used up to 7 feet deep in shales. Measured vertical permeabilities have been in the same ranges mentioned above.

5.2 Comparisons with Other Methods. The accuracy and lack of false negatives of the TSB can be evaluated by the comparisons with SDRI data shown on Figure 9 and with laboratory data from undisturbed samples given on Figure 10. Of the 11 known cases where both field methods were used on the same test pads/liners the mean ratio of their conductivities was 1.1 (TSB higher). In three known cases, the TSB proved failure defects in test pads that laboratory tests did not show, indicating the TSB avoids false positives. Experience to date can be summarized as:

5.2.1 Recompacted Clays. The vertical permeability (k_v) as obtained from laboratory tests, the TSB, and the SDRI generally agree quite well on test pads/liners (11 cases) which have had proper CQA. The laboratory tests tend to underestimate the horizontal permeability.

5.2.2 Natural Clays. Comparisons have only been made with small-scale laboratory tests. In general, there is good agreement with the TSB for vertical permeability, while laboratory tests again underestimate the horizontal permeability.

5.3 Speed. As soon as the test begins, so does the question from the client, "Does it Pass?" It is usual that (k_v) must be less than some specified value (Spec), or that (k_h) must be greater than a different (Spec). Since the maximum possible value for (k_v) is (K1), as soon as (K1<Spec), one knows the test for (k_v) must pass. Likewise, since (K2) is the minimum possible value for (k_h), if the long-term (K2) is greater than (Spec), the test for (k_h) must pass.

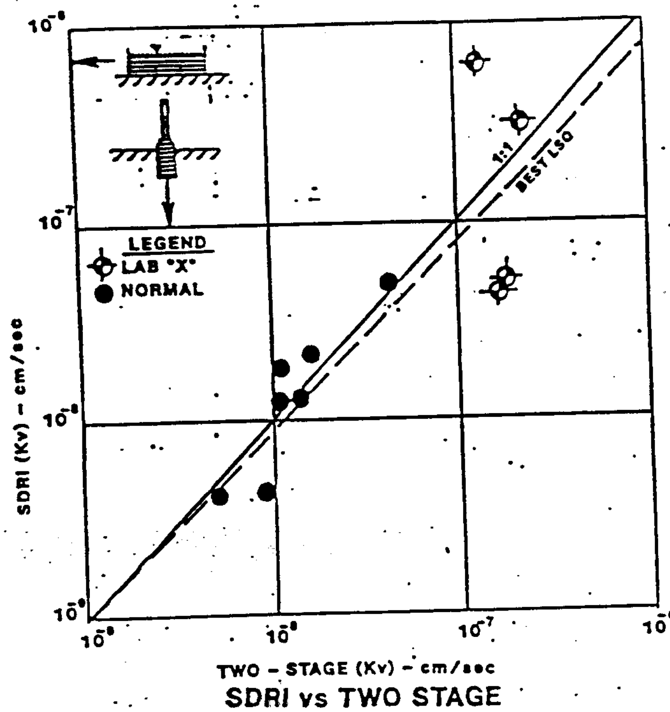


FIGURE 9
TSB AND SDRI RESULTS
(Tests on Same Liners/Test Pads)

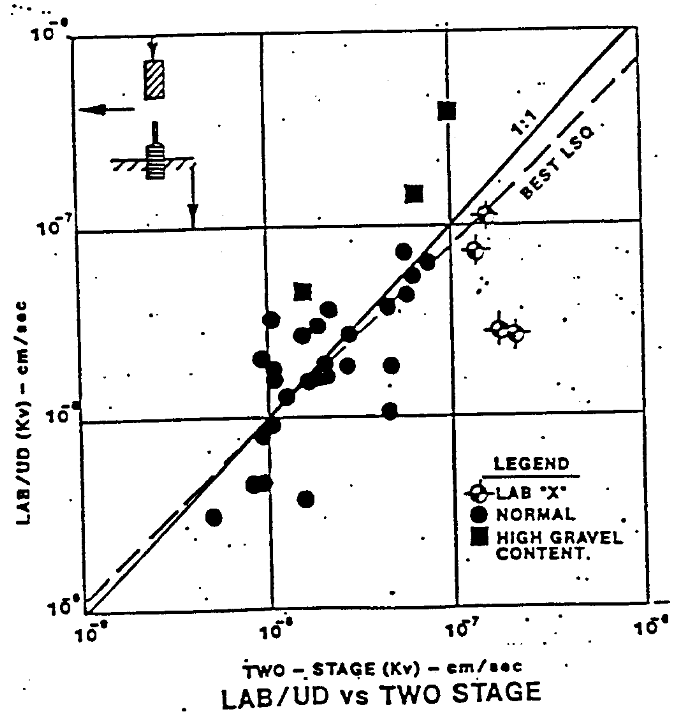


FIGURE 10
TSB AND LAB (k_v) RESULTS
(Tests on Same Liners/Test Pads)

Most of the TSB tests to date in test pads/liners have been for (k_v). The better the pad, i.e., the higher the (Spec/k_v) ratio, the sooner (K1<Spec). In 90% of the tests where (Spec/k_v>1.7), passing was indicated in 24 hours or less. Some 75% of all tests have indicated passing within 72 hours. A marginal test unit, whose (k_v) is just below (Spec), will require completing Stage 2. In general, each Stage lasts 4 to 14 days, the longer times being required to complete a test in lower permeability materials.

5.4 Volume Tested. A single typical TSB test permeates a volume around 0.6 to 1.1 cubic feet, or 60 to 200 times the volume of a typical plug tested in the laboratory (3 inch diameter, 3 inch height). The usual 5-test program thus tests about 10 to 20% the volume of an SDRI, yet yields about the same values. The TSB has a good balance of soil volume tested and speed.

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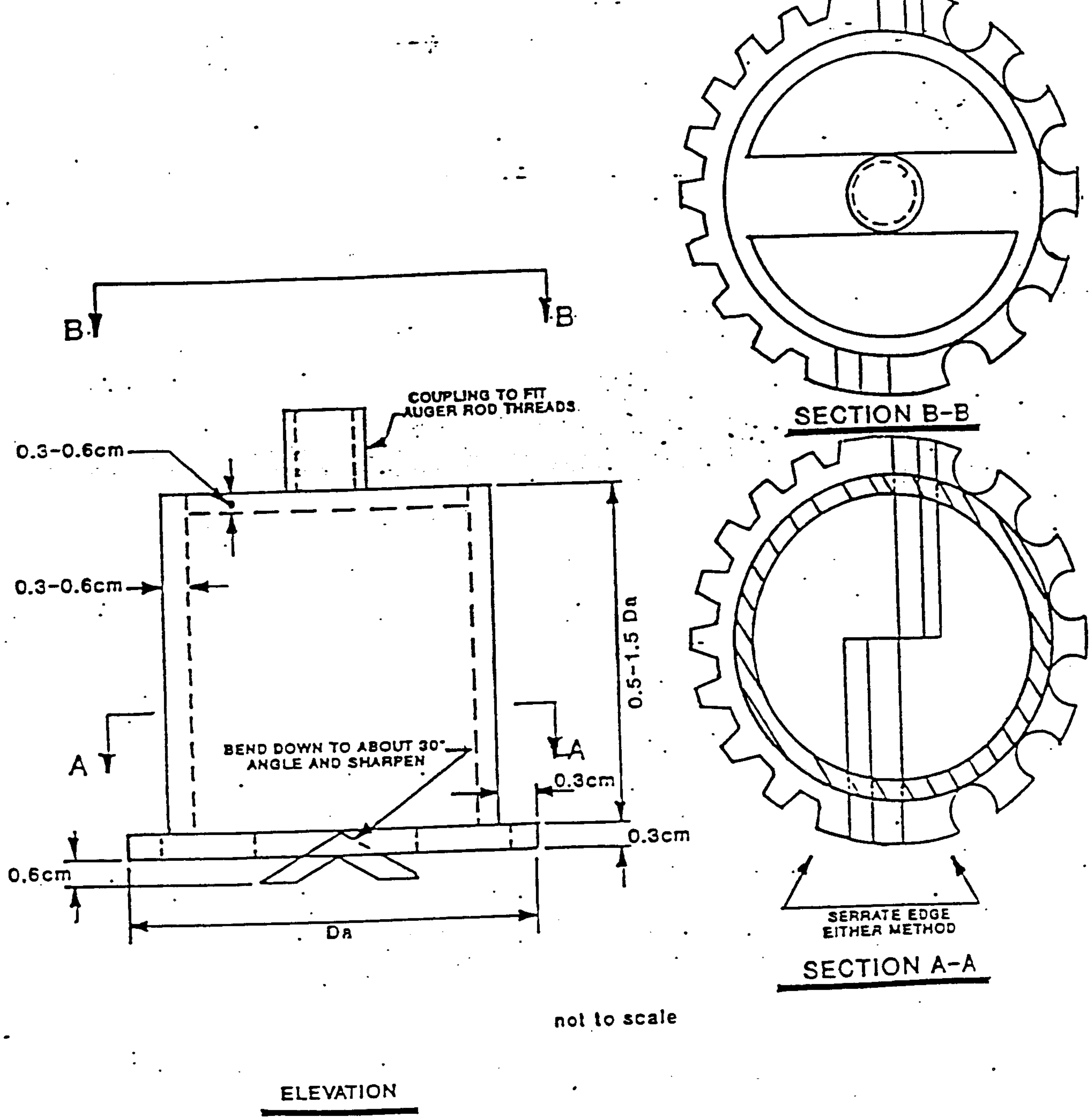
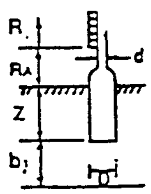


NOTE: FOR FLAT AUGER, Da=D+5cm
FOR REAMER, Da=D -0.1 cm

FLAT BOTTOM REAMING AUGER

STAGE 1 CALCULATIONS



d = 1.27 cm
D = 11.43 cm
Z = 61.0 cm
R_A = 22.9 cm
b_1 = 61.0 cm

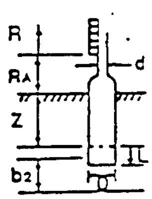
ΔV = 1.27 Δh_c
H = 144.8 +R
$K1 = 0.0384 / \frac{L_N (H_1/H_2)}{t_2 - t_1}$

Ground Elev.: ________
TOC Elev.: ________ (before)
________ (after)
Site Coords: ________

Project: ________
File No.: ________
Test No.: ________
Page: ________

Date	Time	Δt (hrs.)	Δt (sec.)	R (cm)	H1 (cm)	H2 (cm)	K1 (cm/sec)	C (cm)	H2' (cm)	K1' (cm/sec)	Temp. (°C)	R_t Factor	$K1'_t$ (cm/sec)	Cum Vol. (cc)	Cum. Hrs.	Remarks
8/01	0800	—	—	64.8	—	209.6	—	0.0	—	—	21	—	—	0.0	0.0	START
	0830	0.50	1800	47.8	209.6	192.6	1.80E-06	0.0	192.6	1.80E-06	21	0.97	1.76E-06	21.5	0.5	
	0900	0.50	1800	36.3	192.6	181.1	1.31E-06	0.0	181.1	1.31E-06	21	0.97	1.27E-06	36.0	1.0	
	1000	1.00	3600	19.7	181.1	164.5	1.03E-06	0.2	164.3	1.04E-06	22	0.96	9.99E-07	57.1	2.0	END RUN
	1001	-	-	66.7	-	211.5	—	0.0	—	—	22	—	—	-	2.0	REFILL
	1200	1h+59m	7140	47.0	211.5	191.8	5.26E-07	0.6	191.2	5.44E-07	23	0.94	5.09E-07	82.0	4.0	
								etc.								
8/05	1700			50.0		194.8					26				105.0	
8/06	0800	15.00	54000	38.1	194.8	182.9	4.49E-08	-2.8	185.7	3.39E-08	19	0.94	3.20E-08	205.5	120.0	STOP

STAGE 2 CALCULATIONS



d = 1.27 cm
D = 10.16 cm
Z = 61.0 cm
R_A = 22.9 cm
b_2 = 53.3 cm

L = 15.2 cm
ΔV = 1.27 Δh_c
H = 144.8 +R
$K2 = 0.01570 \frac{L_N (H_1/H_2)}{t_2 - t_1}$

Ground Elev.: ________
TOC Elev.: ________ (before)
________ (after)
Site Coords: ________

Project: ________
File No.: ________
Test No.: ________
Page: ________

Date	Time	Δt (hrs.)	Δt (sec.)	R (cm)	H1 (cm)	H2 (cm)	K2 (cm/sec)	C (cm)	H2' (cm)	K2' (cm/sec)	Temp. (°C)	R_t Factor	$K2'_t$ (cm/sec)	Cum Vol. (cc)	Cum. Hrs.	Remarks
8/06	0930	—	—	65.4	—	210.2	—	-	—	—	20	—	—	0.0	0.0	START
	1000	0.5	1800	59.4	210.2	204.2	2.52E-07	0.0	204.2	2.52E-07	21	0.99	2.49E-07	7.6	0.5	
	1030	0.5	1800	54.3	204.2	199.1	2.21E-07	+0.2	198.9	2.28E-07	22	0.96	2.19E-07	14.1	1.0	
	1130	1.0	3600	45.7	199.1	190.5	1.92E-07	+0.3	190.2	2.00E-07	23	0.94	1.87E-07	24.9	2.0	
	1330	2.0	7200	33.3	190.5	178.1	1.47E-07	+1.3	176.8	1.62E-07	24	0.91	1.48E-07	40.6	4.0	
							etc.									
8/09	0730			21.3		166.1					16			-	70.0	
	1600	8.5	30600	9.2	166.1	154.0	3.88E-08	+1.1	152.9	4.25E-08	19	1.07	4.56E-08	267.9	78.5	STOP

FIGURE 3

APPENDIX A

SAMPLE CALCULATION
FOR
2-STAGE FIELD PERMEABILITY TEST

NOTE: This is an idealized case exhibiting virtually perfect behavior, and is not to be considered representative of field behavior.

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JOB SAMPLE – "A"
SHEET NO. 1 OF
CALCULATED BY [signature] DATE 08 Aug 91
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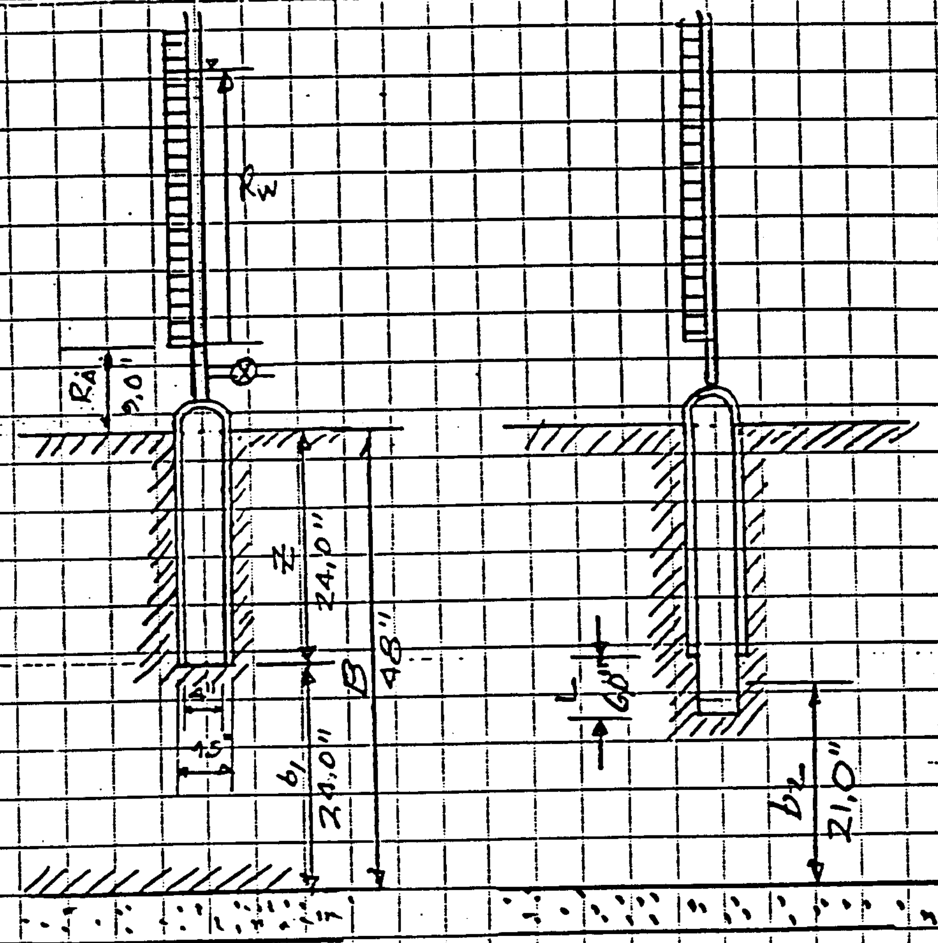
SAMPLE 2-STAGE CALCULATION – HYPOTHETICAL TEST "A"

1. TEST SETUP



Note: Water seeped into casing during bentonite sealing. Therefore, use casing OD = 4.5" for Stage 1 Only.

TO AVOID HYDRAULIC FRACTURING:

HEAD < 1.25 × OVERBURDEN AT CASING BOTTOM

$62.4\ \frac{LB}{FT^3}\ H_{FT} < 1.25 \times 2.0^{FT} \times 124.8\ {}^{LB}/_{FT^3}$

$H^{FT} < 5.0\ FT$

or $R_W < 5.0 - 2.0 - 0.75 = 2.25\ FT = 27.0^{IN}$

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2. TEST DATA

STAGE 1 DATA

Date	Time	RW (in.)	ØC (in.)	Temp. (°F)	TEG (in)
8/01	08:00	25.50	—	70	13.00
	0830	18.81	0	70	13.00
	0900	14.31	0	70	13.00
	1000	7.75	+0.06	72	13.06
Rf.	1001	26.25	—	72	13.06
	1200	18.50	+0.25	74	13.31
	1600	13.88	+1.00	80	14.31
Rf.	1601	26.00	—	80	14.31
8/02	0800	15.81	-1.50	65	12.81
	1700	14.06	+1.31	74	14.12
8/03	0800	9.06	-1.25	68	12.87
	1600	8.38	+1.06	76	13.93
8/04	0800	3.75	-1.44	62	12.49
Rf.	0801	26.50	-	62	12.49
	1701	24.88	+0.50	71	13.00
8/05	0700	20.88	-0.62	66	12.37
	1700	19.69	+1.25	78	13.62
8/06	0800	15.00	-1.12	67	12.50

STAGE 2 DATA

Date	Time	RW (in.)	ØC (in.)	Temp. (°F)	TEG (in.)
8/06	0930	25.75	—	68	12.56
	1000	23.39	0.00	70	12.56
	1030	21.38	+0.06	72	12.62
	1130	18.00	+0.13	74	12.75
	1330	13.12	+0.50	76	13.25
	1700	7.12	+0.69	80	13.94
R	1701	26.56	-	80	13.94
8/07	0700	6.06	-1.12	70	12.82
R	0701	25.25	—	70	12.82
	1200	19.88	+0.31	74	13.03
	1700	15.94	+0.56	78	13.59
8/08	0800	3.81	-1.50	62	12.09
R	0802	26.31	-	62	12.09
	1700	20.56	+1.69	74	13.78
8/09	0730	8.38	-1.56	60	12.22
	1600	3.62	+0.44	66	12.66

READ FROM TEG

CALCULATED FROM TEG LEVELS

READ FROM TEG

Calculate from TEG Levels

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3. STAGE 1

A. CALCULATE FACTOR [Eq. 3.5-4]

$$K1 = F_1 \frac{Ln(H_1/H_2')}{t_2 - t_1} \quad \text{where } F_1 = \frac{\pi d^2}{11 D}\left(1 - D/4b_1\right)$$

$d = 0.50'' = 1.27$ cm (See sketch on p. 1)
$D = 4.50'' = 11.43$ cm (See note on p. 1)
$b_1 = 24.0'' = 60.96$ cm (See sketch on p. 1)

$$F_1 = \frac{\pi (1.27)^2}{11 \times 11.43}\left(1 - \frac{11.43}{4 \times 60.96}\right)$$

$$\boxed{F_1 = 0.03841 \text{ cm}}$$

B. CALCULATIONS

i. $K1\ H1 = B + R_A + R_{W1} = 48.00 + 9.00 + R_{W1} = 57.00 + R_{W1}$
$H2' = B + R_A + R_{W2} - C = 48.00 + 9.00 + (R_{W2} - C) = 57.00 + (R_{W2}$

i. Period 1700 08/02 – 0800 08/03

$$K1 = .03841 \frac{Ln[(57.00 + R_{W1})/(57.00 + R_{W2} + C)]}{\Delta t \text{ (sec)}}$$

$H1 = 57.00 + 14.06 = 71.06$
$H2' = 57.00 + 9.06 + 1.25 = 67.31$

Note: TEG fell 1.25" in this period. ∴ 1.25' of the Test drop is purely temp.

$\Delta t = 15 \text{ hrs} \times 3600 \text{ s/hr} = 54000$ sec.

$$K1 = 0.03841 \text{ cm} \frac{Ln(71.06/67.31)}{54000 \text{ sec}} = 3.86 \times 10(-8)$$

Now, apply viscosity correction
$Temp = \frac{1}{2}(74 + 68) = 71°$
From chart, viscosity Factor $= 0.96 = R_T$

$$K1_{\text{I}} = R_T \cdot K1c = 0.96 \times [3.86 \times 10(-8)] = 3.71 \times 10(-8) \frac{cm}{sec}$$

See p. 6 for Tabulation of all points

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4. STAGE 2

A. CALCULATE FACTOR [Eq. 3.5-5, with a = -1]

$$K2 = F \frac{Ln(H_1/H_2)}{t_2 - t_1}$$

where: $F = \left(\frac{1}{f}\right)\left(\frac{d^2}{16L}\right) Ln\left[\frac{U(D,0)}{U(D,2b_2)}\right]$

$$f = 1 - 0.5623 e^{-1.566(L/D)}$$

L = Extension below Casing (6 inches = 15.24 cm)

D = Borehole diameter = ID of Casing (4 inches)

$r_o = D/2$

$b_2 = B - Z + L/2 = 48.00'' - 24.00'' - 6.00''/2 = 21.00''$

$$U(1,D,Z) = \frac{(2Z/D + L/D) + \sqrt{1 + [2Z/D + L/D]^2}}{2Z/D - L/D + \sqrt{1 + [2Z/D - L/D]^2}}$$

$L/D = 6''/4'' = 1.5$

$$\therefore f = 1 - 0.5623 e^{-1.566(1.5)}$$
$$= 0.9463$$

$$U(1,r_o,0) = U(1,D,0) = \frac{(0+1.5) + \sqrt{1 + [0+1.5]^2}}{(0-1.5) + \sqrt{1 + [0-1.5]^2}} = \frac{1.5 + \sqrt{1+1.5^2}}{-1.5 + \sqrt{1+1.5^2}}$$

[U(1,r0,0) Eq. 3.5-5]

$$= [1.5 + \sqrt{1+1.5^2}]^2$$

$$= 10.9083$$

$2b_2 = 2 \times 21 = 42''$

$$U(1,r_o,2b_2) = U(1,D,42) = \frac{(84/4 + 1.5) + \sqrt{1 + [84/4 + 1.5]^2}}{(84/4 - 1.5) + \sqrt{1 + [84/4 - 1.5]^2}} = \frac{22.5 + \sqrt{1+22.5^2}}{19.5 + \sqrt{1+19.5^2}}$$

[U(1,r0,2b2) Eq. 3.5-5]

$$= 1.1537$$

$$\therefore F = \frac{1}{0.9463} \times \frac{1.27^2 \text{ cm}^2}{16 \times 15.24 \text{ cm}} Ln(10.9083/1.1537)$$

$$\boxed{F = 0.01570 \text{ cm}}$$

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5.B. Calculation for K2' (See p.7 for the data points)

This is virtually the same calculation as on p.8

Period (hrs)	Calculation		K2'
0.0–2.0	$\frac{24.9\times1.80+21.9\times1.80+18.7\times3.60}{1.80+1.80+3.60}$	$= \frac{151.56}{7.20} = 21.05\times10(-8)$	$2.11\times10(-7)$
2.0–21.5	$\frac{14.8\times7.20+11.0\times12.60+7.52\times50.34}{7.20+12.60+50.34}$	$= \frac{623.72}{70.14} = 8.89\times10(-8)$	$8.89\times10(-8)$
21.5–31.5	$\frac{5.94\times17.94+4.74\times18.00}{17.94+18.00}$	$= \frac{191.88}{35.94} = 5.34\times10(-8)$	$5.34\times10(-8)$
31.5–55.5	$\frac{4.46\times54.00+4.55\times32.28}{54.00+32.28}$	$= \frac{387.71}{86.28} = 4.49\times10(-8)$	$4.49\times10(-8)$
55.5–78.5	$\frac{4.49\times52.20+4.56\times30.60}{52.20+30.60}$	$= \frac{373.91}{82.80} = 4.52\times10(-8)$	$4.52\times10(-8)$

The last two periods are virtually identical and last some 24 hours each (appropriate for this permeability level)

$$\therefore K2' = \frac{387.71+373.91}{86.28+82.80} = \frac{761.62}{169.08} = 4.50\times10(-8)$$

$$\boxed{K2' = 4.50\times10^{-8}\ cm/sec}$$

6.0 CALCULATE Kv AND Kh

A. SMEAR.

Check by K2/K1 Ratio needed for next step

$$K2'/K1' = \frac{4.50\times10(-8)}{3.21\times10(-8)} = 1.40$$

Probably no smear since > 1:1

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SCALE:

B. EQUATION (For shortcut, see p. 12)

$$K2'/K1' = \left(\frac{G1m}{G1}\right)\left(\frac{G2}{G2S}\right) \qquad [\text{Eq. } 4.2\text{-}5]$$

where $G1m/G1 = (1/m)\,[1 + a(D_1/4mb_1)] \,/\, [1 + a(D_1/4b_1)]$

but, $D_1 = 11.43$ cm (p. 3) $\quad a = -1$ (Perm. Base)

$b_1 = 20.96$ cm (p. 3)

$$G1m/G1 = (1/m)\left[1 - \frac{11.43}{4(m)(20.96)}\right] \Big/ \left[1 - \frac{11.43}{4(20.96)}\right]$$
$$= (1/m)\left(\frac{1}{.8636}\right)\left(1 - \frac{1}{21.33m}\right)$$

$$G2/G2S = \frac{m^2\{\text{Ln}[v(1, r_0, 0)] + a\,\text{Ln}[v(1, r_0, 2b_2)]\}}{\text{Ln}[v(m, r_0+T, 0)] + a\,\text{Ln}[v(m, r_0, 2b_2)] + p\,\text{Ln}[v(m, r_0, 0)/v(m, r_0+T, 0)]}$$

$a = -1$

$p = 1$

$$\text{Thus } G2/G2S = \frac{m^2\,\text{Ln}[v(1, r_0, 0)/v(1, r_0, 2b_2)]}{\text{Ln}[v(m, r_0, 0)/v(m, r_0, 2b_2)]}$$

$$v(1, r_0, 0) = \left[L/D + \sqrt{1 + (L/D)^2}\right]^2 = \left[1.5 + \sqrt{1 + 1.5^2}\right]^2 = 10.90833$$

$$v(1, r_0, 2b_2) = \frac{4b_2/D_2 + L/D_2 + \sqrt{1 + (4b_2/D_2 + L/D_2)^2}}{4b_2/D_2 - L/D_2 + \sqrt{1 + (4b_2/D_2 - L/D_2)^2}}$$

$b_2 = 21''$ (See p. 1)

$D_2 = 4.0'$ (See p. 1)

$$= \frac{4(21/4) + 6/4 + \sqrt{1 + (4 \times 21/4 + 6/4)^2}}{4(21/4) - 6/4 + \sqrt{1 + (4 \times 21/4 - 6/4)^2}} = \frac{45.0222}{39.0256}$$

$v(1, r_0, 2b_2) = 1.15366$

$$G2/G2S = \frac{m^2\,\text{Ln}[10.90833/1.15366]}{\text{Ln}[v(m, r_0, 0)/v(m, r_0, 2b_2)]} = \frac{2.24659\,m^2}{\text{Ln}[v(m, r_0, 0)/v(m, r_0, 2b_2)]}$$

$$K2'/K1' = \frac{1}{m}\,\frac{1}{.8636}\left(1 - \frac{1}{21.33m}\right) \cdot \frac{2.24659\,m^2}{\text{Ln}[v(m, r_0, 0)/v(m, r_0, 2b_2)]}$$

$$= 2.3738\,m\left(1 - \frac{1}{21.33m}\right)\frac{1}{\text{Ln}[v(m, r_0, 0)/v(m, r_0, 2b_2)]}$$

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(i) TRY $m = 2.0$

$$u(m, r_0, 0) = \left[mL/D_2 + \sqrt{1 + (mL/D_2)^2} \right]^2$$
$$= \left[1.5m + \sqrt{1 + (1.5m)^2} \right]^2$$
$$u(2, r_0, 0) = \left[1.5 \times 2 + \sqrt{1 + (1.5 \times 2)^2} \right]^2 = 6.1623^2$$
$$= 37.9737$$

$$u(m, r_0, 2b_2) = \frac{4mb_2/D_2 + mL/D + \sqrt{1 + (4mb_2/D_2 + mL/D_2)^2}}{4mb_2/D_2 - mL/D + \sqrt{1 + (4mb_2/D_2 - mL/D_2)^2}}$$
$$= \frac{4m\,21/4 + m\,6/4 + \sqrt{1 + (4m\,21/4 + m\,6/4)^2}}{4m\,21/4 - m\,6/4 + \sqrt{1 + (4m\,21/4 - m\,6/4)^2}}$$
$$= \frac{22.5m + \sqrt{1 + (22.5m)^2}}{19.5m + \sqrt{1 + (19.5m)^2}}$$
$$u(2, r_0, 2b_2) = \frac{22.5 \times 2 + \sqrt{1 + (22.5 \times 2)^2}}{19.5 \times 2 + \sqrt{1 + (19.5 \times 2)^2}} = \frac{90.0111}{78.0128} = 1.1538$$

$$K_2'/K_1' = 1.40 \overset{?}{=} 2.3738(2.0)\left(1 - \frac{1}{21.33 \times 2}\right) \frac{1}{\ln\left[37.9737/1.1538\right]}$$
$$\overset{?}{=} 4.7476\,(.9766)\,\frac{1}{3.4938}$$
$$1.40 > 1.327$$

$\therefore$ need larger m

ii. Try $m = 2.4$

$$u(2.4, r_0, 0) = \left[1.5 \times 2.4 + \sqrt{1 + (1.5 \times 2.4)^2}\right]^2 = 53.8214$$
$$u(2, r_0, 2b_2) = \frac{22.5 \times 2.4 + \sqrt{1 + (22.5 \times 2.4)^2}}{19.5 \times 2.4 + \sqrt{1 + (19.5 \times 2.4)^2}} = 1.1538$$
$$K_2'/K_1' = 1.40 \overset{?}{=} 2.3738\,(2.4)\left[1 - \frac{1}{21.33 \times 2.4}\right] \frac{1}{\ln\left[53.8214/1.1538\right]}$$
$$\overset{?}{=} 5.6971z\,(.9805)\,(1/3.8426)$$
$$1.40 < 1.454$$

$\therefore$ need smaller m

Successive trial-and-error yields $m = 2.27$

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C. CALCULATE Kv, Kh

Note: ONE CAN AVOID THE CALCULATIONS of pp. 10 and 11 is BY USING THE ATTACHED NOMOGRAPH (Fig. 7 – Text)

The easiest calculation is USING THE STAGE 1 EQUATION:

$$K_v = \frac{G_{1m}}{G_{1i}} K_1' \qquad [\text{Eq. } 41\text{-}2]$$

$$= \frac{1}{m}\left[\frac{1 - D_1/4mb_1}{1 - D_1/4b_1}\right] K_1'$$

with $D_1 = 4.50''$
$b_1 = 24.0''$
$m = 2.27$

$$K_v = \frac{1}{2.27}\left[\frac{1 - \frac{4.5}{4(2.27)(24)}}{1 - \frac{4.5}{4(24)}}\right] \times [3.21 \times 10(-8)]$$

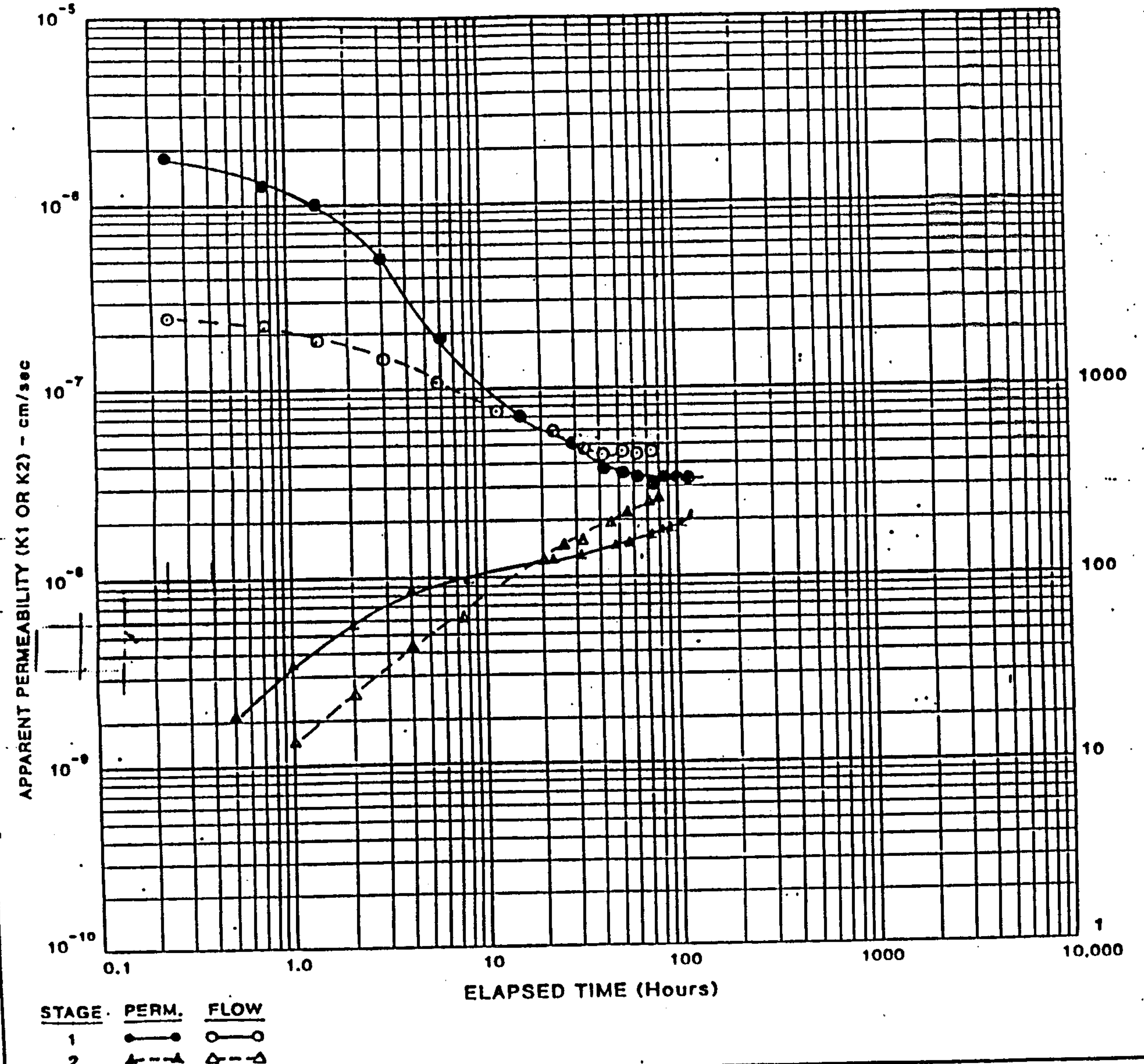
$$= \frac{1}{2.27}\left[\frac{.9792}{.9464}\right] 3.21 \times 10(-8)$$

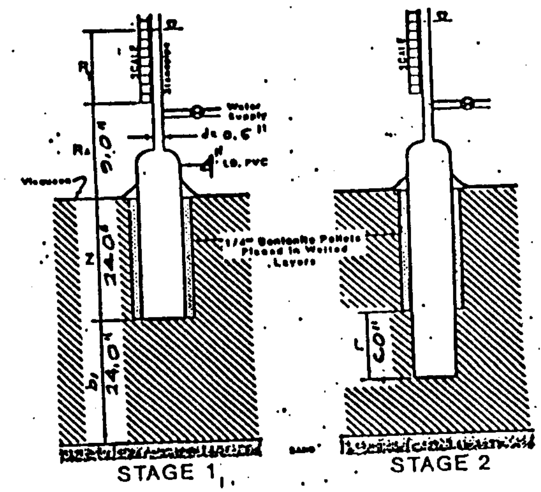
$$\boxed{K_v = 1.45 \times 10(-8) \text{ cm/sec}}$$

$$K_h = m^2 K_v \qquad [\text{Eq. } 41\text{-}5]$$

$$= 2.27^2 [1.45 \times 10(-8)]$$

$$\boxed{K_h = 7.47 \times 10(-8)}$$





TWO - STAGE
FIELD PERMEABILITY TEST
SUBBASE TEST PAD

SAMPLE TEST "A"
EREWHON, CALIVANIA

GEOTECHNICAL SERVICES BY
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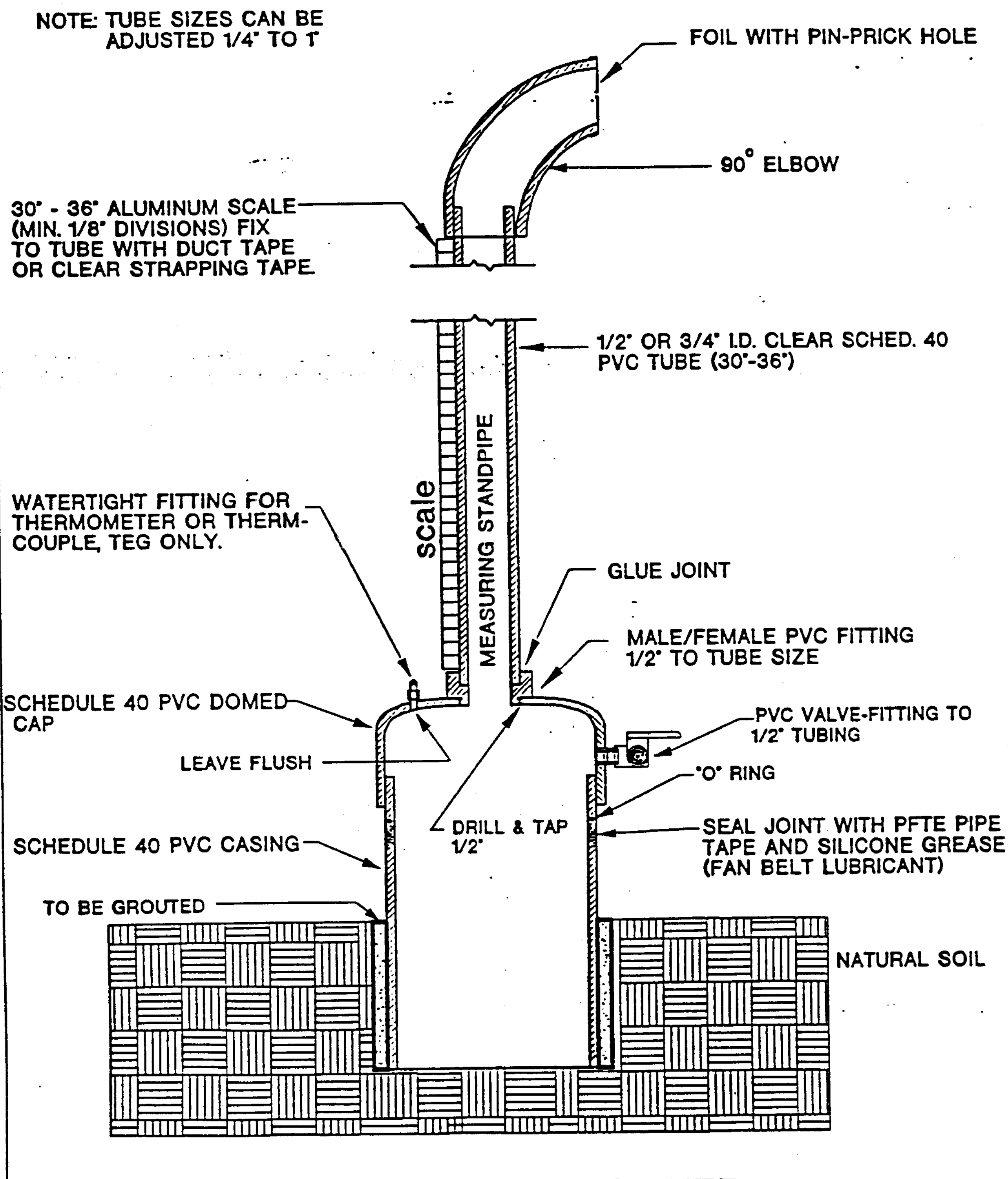
Baton Rouge, LA   Lake Charles, LA

Project Engineer:	Drawn by:	Checked by:
G.P. BOUTWELL	SJT	C.N.TSAI
File No.: 91-081	Date:	Figure No.:

Title: BEHAVIOR OF TEST FP- "A"



TYPICAL PERMEAMETER

1450 10-6-92

TEG 1 FILLED 32."3/8

1508

TEG 2 FILLED 33 15/16"

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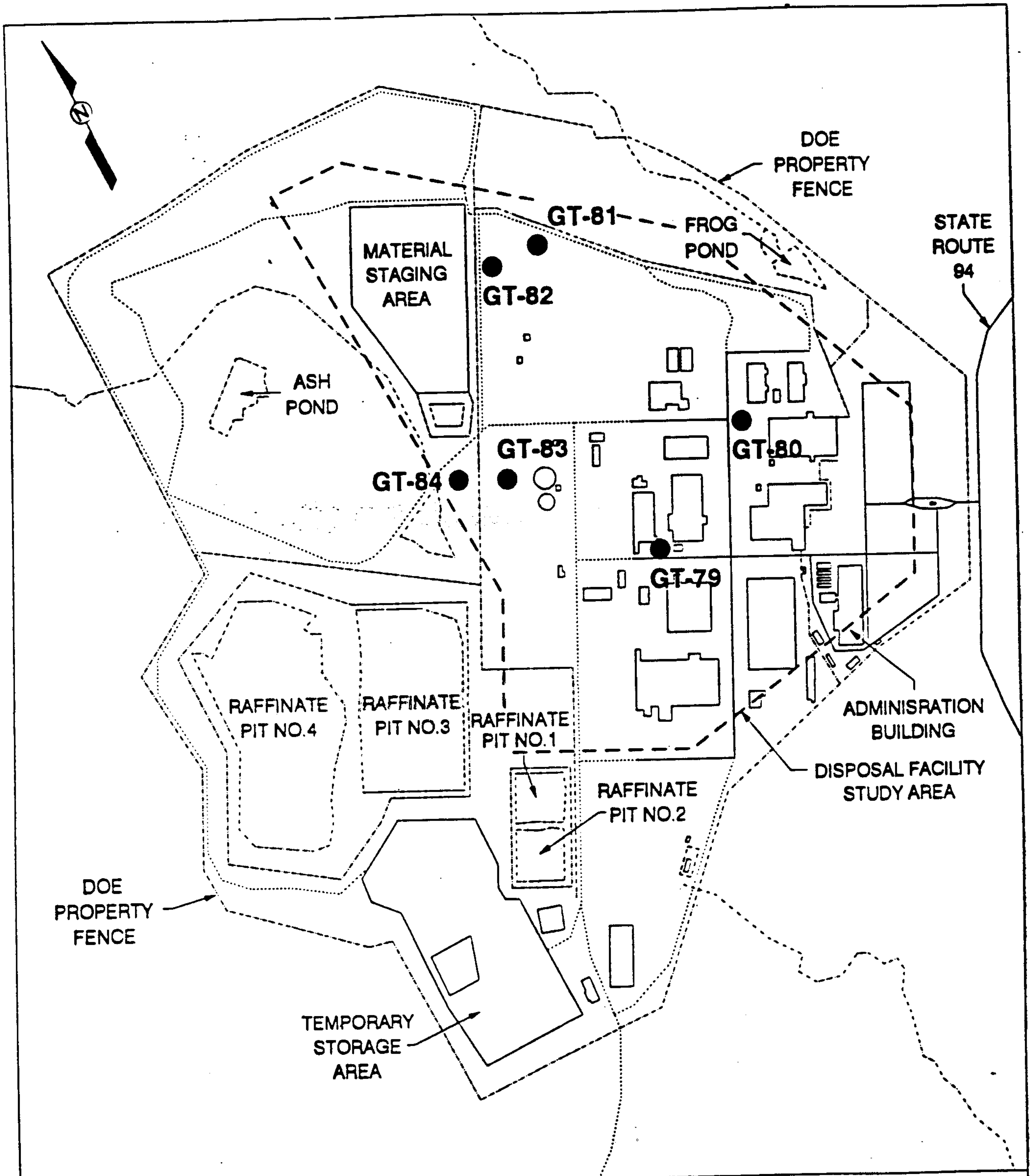
ATTACHMENT 7

LOCATIONS OF WATER/LEACHATE PERMEABILITY TESTING SAMPLES



SMALL DIAMETER GEOTECHNICAL BOREHOLES LOCATION MAP

FIGURE 2-1

REPORT NO.:			EXHIBIT NO.:	A/CP/087/0892	
ORIGINATOR:	SDG	DRAWN BY:	GLN	DATE	8/92

ATTACHMENT 8
SUMMARY OF LEACHATE SYNTHESIS METHODOLOGY

Permeability testing was accomplished by obtaining undisturbed samples of site soils (Ferrelview Formation and Clay Till) and subjecting these samples to triaxial permeability testing (ASTM Method D-5084). Samples were initially tested with water as a permeant, then the same samples were tested with leachate permeant.

The leachate was generated by mixing liquids generated by modified batch leach testing of chemically stabilized/solidified raffinate sludge (CSS Sludge), untreated radioactive soils, and untreated chemically contaminated soils. The liquids from these leaching tests were combined at the following ratio in order to provide a representative leachate:

> 2:1:1 (CSS Treated Sludge:Untreated Radioactive Soils:Untreated Chemical Contaminated Soils)

This ratio of materials is based upon proposed waste quantities including bulking factors for treated wastes. These quantities are found in the latest version of the PMC's Waste Management Quarterly Report.

Additional details relating to the leaching methodology and associated sampling of waste materials are presented in the pertinent references listed in Attachment 10.

ATTACHMENT 9

COMPARATIVE CALCULATIONS

TRAVEL TIME AND PERMITTIVITY

COMPARISON OF HYDRAULIC CONDUCTIVITY DATA

DATA SET	HYDRAULIC CONDUCTIVITY [K] (cm/sec)	POROSITY [n] (6)	EFFECTIVE POROSITY [n_e] (7)	FORMATION THICKNESS [b] (ft)	SEEPAGE VELOCITY [P] (cm/sec) (8)	PERMITTIVITY [t] (sec^{-1}) (9)	TRAVEL TIME [V] (YEARS) (10)
10 CSR 25-7[1]	1.0E-07	0.40		30	2.5E-07	1.1E-10	116
			0.08	30	1.25E-06		23
MKF & JEG 1991 [2]	3.1E-08	0.40		20	7.7E-08	5.1E-11	250
			0.08	20	3.9E-07		50
TSB[3]	1.28E-08	0.40		20	3.2E-08	2.1E-11	604
			0.08	20	1.6E-07		121
1992 LAB (H_2O) [4]	1.5E-08	0.40		20	3.8E-08	2.5E-11	516
			0.08	20	1.9E-07		103
1992 LAB (LEACH) [5]	2.7E-09	0.40		20	6.8E-09	4.4E-12	2865
			0.08	20	3.4E-08		573

EXPLANATION:

1 10 CSR 25-7 - Basic regulatory criteria are 30 ft of soil with K= 1.0E-07 cm/sec.

2 Site suitability data on potential location of a disposal facility: Collapse potential and permeability.

3 Largest logarithmic mean value from Table 2.

4 Largest measured value for water from Table 3.

5 Largest measured value for leachate from Table 3.

6 Average total porosity from unpublished data - MKF & JEG 1992 Draft.

7 Estimated average effective porosity from [6].

8 Seepage velocity - V= Ki/n

9 Permittivity - P = Average hydraulic conductivity + thickness (Koerner, R.M. 1990. Designing with geosynthetics. Prentic-Hall.)

10 Travel time - t = 6/V

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ATTACHMENT 10

LIST OF PERTINENT REFERENCE DOCUMENTS

The following documents are listed for reference in describing background and support activities associated with this effort. Copies of these reports have been submitted under separate cover:

Modified batch leach testing is described in the "Batch Leach Testing Plan", MK-JEG, Rev. 1, Nov. 92.

The chemical soil samples were collected in accordance with the "Soil Sampling Plan for Column Leach and Batch Tests and TCLP Analysis", Rev. 0, May 92.

The radioactive site soils were collected in accordance with the "Stabilization /Solidification/Dewatering Sampling Plan", MK-JEG, Rev. 0, May 91.

The undisturbed soil samples were obtained in accordance with the "Sampling Plan for Determination of Hydraulic Properties of Undisturbed Soils in the Weldon Spring Disposal Facility Study Area", Rev. 1, MK-JEG, Oct. 92.